The Portsmouth Blockmaking Machinery

K. R. GILBERT

A Science Museum Monograph

Cover Photograph:
A block in the rigging of
HMS *Victory*

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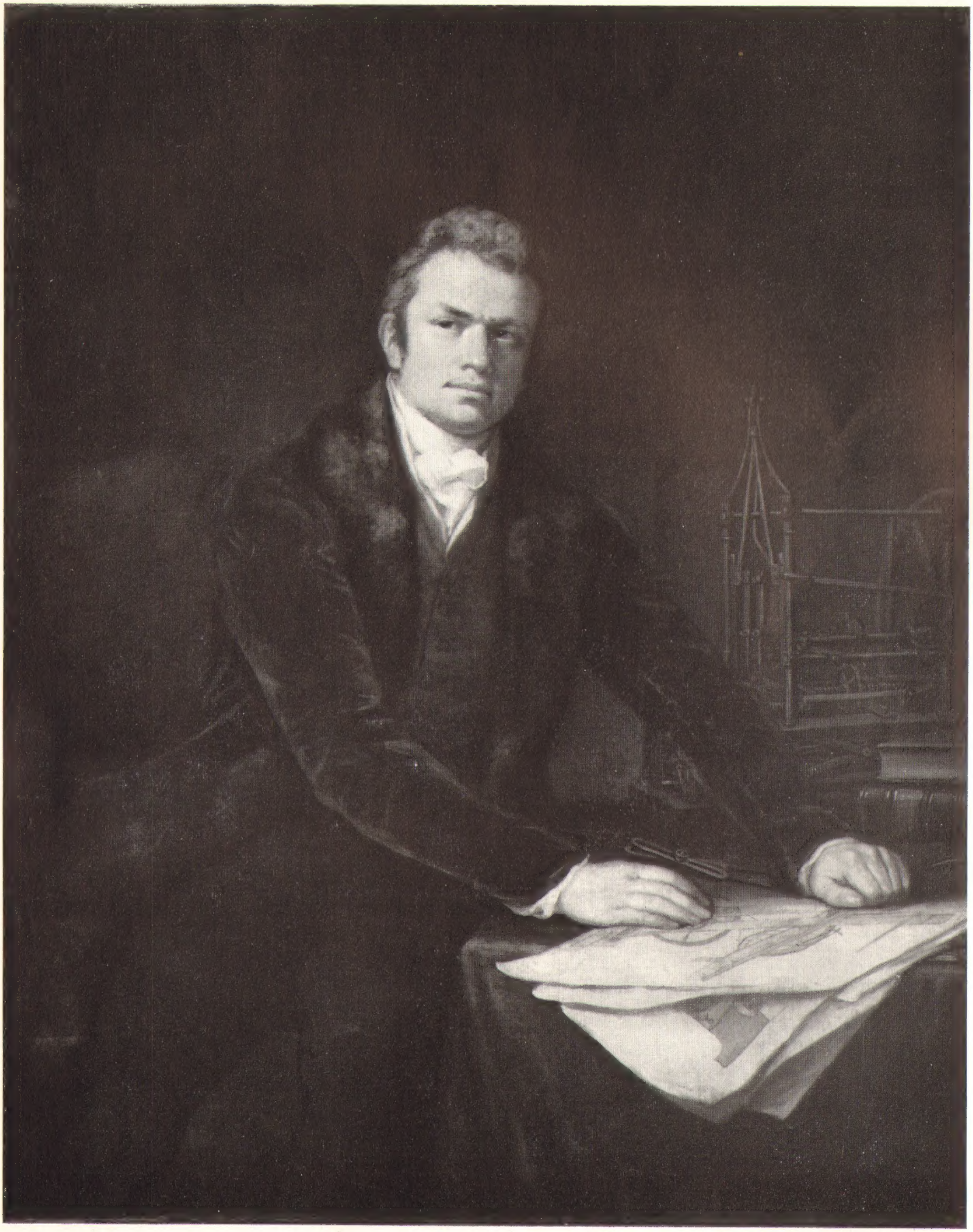


Marc Isambard Brunel (*National Portrait Gallery*)

A Science Museum Monograph

The Portsmouth Block-making Machinery

A pioneering enterprise in mass production

by K.R.Gilbert M.A, D.I.C

Her Majesty's Stationery Office London 1965

First published 1965

Foreword

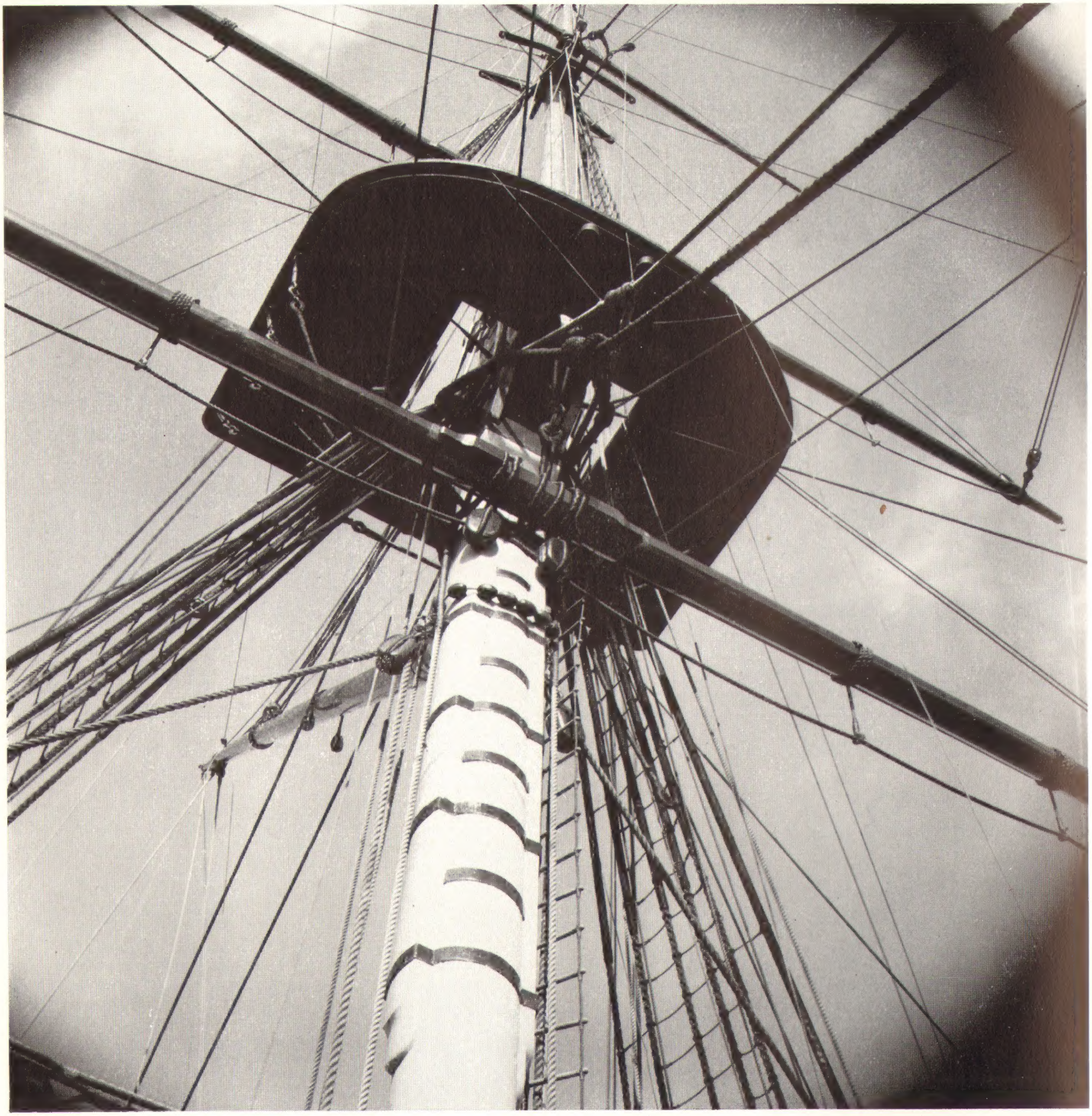
The Science Museum acquired from the Admiralty between 1933 and 1951 a representative group of eight machines from the Portsmouth Block-Making Machinery for the Machine Tool Collection. This machinery is of outstanding historic interest as the first large-scale plant to employ machine tools for mass production.

Besides relating the history of the Machinery and describing it in some detail, this monograph, by using in evidence hitherto unpublished material, settles the century-old controversy as to who should be credited with the invention of the Machinery. The author, Mr K. R. Gilbert, is Keeper of the Department of Mechanical and Civil Engineering.

D. H. Follett
Director

April 1964

1 HMS *Victory*—
Mizen mast and rigging



1 The introduction of machinery for block-making

The machinery for manufacturing ships' blocks which was set up in the Royal Dockyard at Portsmouth at the beginning of the 19th century is of historic importance as the first instance of the use of machine tools for mass production. Priority might perhaps be claimed for Bramah's machinery for making his patent lock or for the interchangeable manufacture of fire arms in France and in America, but those were enterprises on a much smaller scale than the Portsmouth plant, which by 1808 had a yearly output of 130,000 blocks. The pulley block is an article of limited interest, and less so now than in the days of sail; so it was the novelty and interest of the plant as a system of manufacturing machinery that justified the devotion to it of the entire section on 'machinery', amounting to 18 pages and 7 plates, in Rees's great *Cyclopaedia*[1], which was published in 1819, and explains our continued interest in the Portsmouth block-making machinery. During the 19th Century the machinery was described at length in many encyclopaedias: *Britannica, Penny, Edinburgh, Chambers'*. In the *Encyclopaedia Britannica* it appeared in successive editions from the fourth until the ninth in 1875, but was omitted from the tenth in 1902.

The block-making machines were the earliest machine tools of substantial size—that is, excepting clockmakers' tools—to be constructed entirely of metal. Previously metal had been used only sparingly for lathe centres and for screws and cutters, but the framing had been of wood. The use of metal throughout in the block-making machinery, the framing of the largest saws excepted, enabled a great improvement in rigidity and accuracy to be obtained, and became standard in subsequent machine-tool practice.

So well were the machines designed and built that several of them continued in use into the mid 20th Century, and in consequence eight of the more interesting machines survived to be included in the Hand and Machine Tool Collection of the Science Museum. Also seven of the machines remain in the Block Mills at Portsmouth Dock Yard, and three of these are still, at the time of writing, in use. The building of the machinery was the first large undertaking of the distinguished engineer Henry Maudslay and must have influenced machine-tool engineering through his own firm, Maudslay, Sons & Field, and through his employees who later became leading engineers and included such eminent figures as Richard Roberts, James Nasmyth, and Joseph Whitworth.

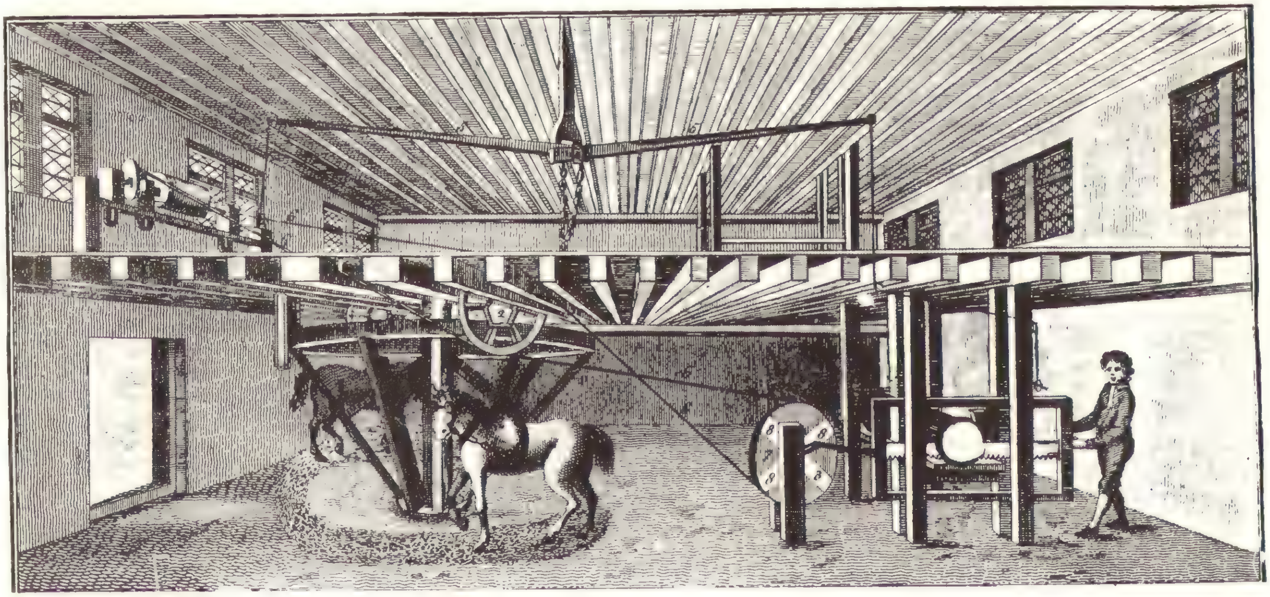
A ship's block consists of at least three parts: a *sheave* or pulley, turning on a *pin,* in a *shell.* The shell is a shaped piece of elm, scored on the surface to hold a rope strap. The sheave is of lignum vitae and in the case of naval blocks was fitted with a bell-metal bearing called a *coak*. The pin formerly made of lignum vitae or other hardwood was usually since the mid 18th-Century made of iron. The block and its components are illustrated in figure 8.

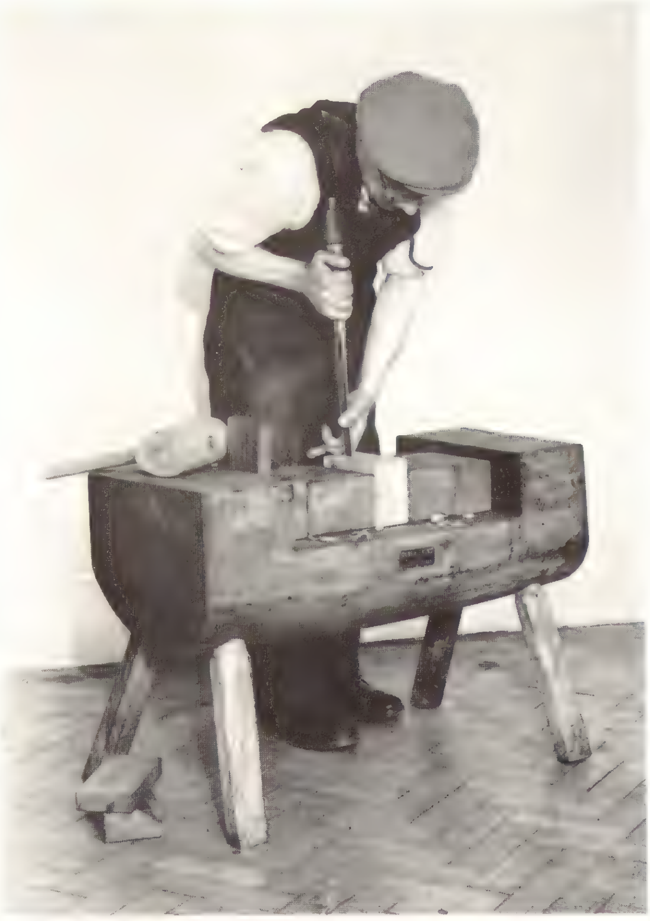
Between 1759 and 1805 the Taylors of Southampton[2] were the leading suppliers of blocks to the Royal Navy. Walter Taylor (1734-1803) who is thought to have been the inventor of the circular saw, was responsible for the introduction of the iron pin and the coak. His son Samuel in a letter[3] dated March 5, 1801 described the manufacture of blocks as follows: 'I will just describe in a few words how we have made our blocks for upwards of twenty-five years—twenty years to my own knowledge. The tree of timber, from two to five loads' measurement, is drawn by the machine under the saw, where it is cut to its proper length. It is then removed to a round saw where the piece cut off is completely shaped, and only requiring to be turned under the saw. The one, two, or three, or four mortises are cut in by hand, which wholly completes the block, except with a broad chisel cutting out the roughness of the teeth of the saw, and the scores for strapping the rope. Every block we make (except more than four machines can make) is done in this way, and with great truth and exactness. The shivers are wholly done by the engines, very little labour is employed about our works, except the removing the things from one place to another.' An illustration of Taylor's mill showing a saw and lathe driven by a horse mill is reproduced as figure 2 from an account[4] of block-making published in 1794.

As far as concerned the shell, the use of machinery was restricted to sawing approximately to shape and to boring for the pin. Mortising, shaping, and scoring the shell were manual operations carried out with chisels, draw-knife, spoke-shave, and gouge on the block of elm suitably wedged in a work bench or stool known as a clave. Squaring down the mortise of the shell with a V-chisel is illustrated in figure 3.

William Dunsterville of Plymouth was also under contract to supply blocks for the Royal Navy. His works were visited in September, 1802 by Simon Goodrich[5] who made drawings of the wooden-framed machinery which included reciprocating and circular saws, lathes for turning the sheaves and pins, boring machines for the sheaves and coaks, and a machine with two circular saws for cutting the mortises.

The number of blocks used in a navy under sail was very large—a 74-gun ship required 922 blocks[4]—and it was estimated that the annual consumption by the Royal Navy at the beginning of the 19th Century was 100,000. The use of blocks in a warship of the period is shown in figures 1 and 4. The proposal that the Government should undertake the manufacture of blocks and other naval stores by power-driven machinery was due to Brigadier General Sir Samuel Bentham, K.S.G , who in

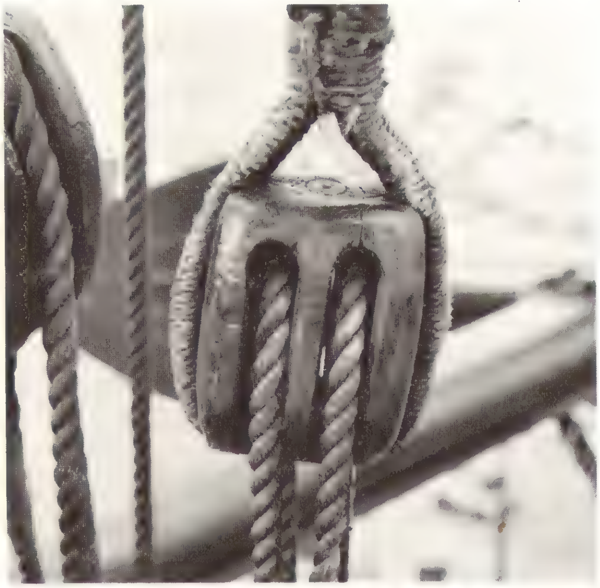




2 A block mill in 1794

3 Block making by hand: mortising the shell

1796 had been appointed to the new office of Inspector-General of Naval Works. Born in 1757 he was educated as apprentice to the Master Shipwright at Woolwich Dockyard and, after a period at sea, he had been sent on a tour of northern European ports and had eventually taken service in Russia as a military and naval engineer and constructor. After gaining his military rank and knighthood in Russia, he returned to England in 1791. He made a study of the possibilities of wood-working by machinery and embodied his conclusions in his comprehensive patent of 1793 (No. 1838). This patent included planing with rotary cutters, a mortising machine, and other wood-working machines. As Inspector-General he effectively re-organised the administration of the dockyards and introduced technical improvements, including inventions of his own, and, not without opposition, he had a 12 hp steam engine installed at Portsmouth Dockyard. By 1805 there were two 30 hp steam engines there, one by Boulton and Watt, and the other by Murray and Wood, replacing the earlier engine, to pump water and to drive the machinery. Bentham's office was abolished in 1807 and he was then appointed a Commissioner of the Navy. He died in 1831. Bentham's mechanist and manager at Portsmouth was Simon Goodrich (1773-1847), whose journal and other papers[5,6]. preserved in the Science Museum are a source of information on the installation of the block-making machinery.



4 A double block in the rigging of HMS *Victory*

In 1801 Bentham was approached by Marc Isambard Brunel[3] with a scheme for manufacturing ships' blocks which, on the former's recommendation, was adopted by the Admiralty. Brunel was born in Normandy in 1769 and served as an officer in the French Navy until the French Revolution, when, because of his royalist sympathies, he had to escape from France and became a refugee in the United States.

There he practised civil engineering, became Chief Engineer of New York, and was in 1796 admitted to citizenship. In 1798 he left for England to marry Miss Sophia Kingdom, whom he had met in France and whose brother was Under Secretary to the Navy Board. While still in America Brunel had become interested in devising block-making machinery and in 1801 took out a British patent (No. 2478) for block-making, comprising: a mortising machine with two chisels and ratchet feed; a side- and edge-sawing machine; a shaping engine, which served for both shaping and boring the shell; and a sheave cutter. Although these machines differed from and were less sophisticated than the machinery subsequently built, Brunel had proceeded so far as to order models from Henry Maudslay, and through his brother-in-law had offered the machinery to Taylor, who had the larger part of the business of supplying the Royal Navy. The first part of Taylor's reply to Kingdom has already been quoted on page 2. He went on to say:

> 'My father has spent many hundreds a year to get the best mode, and most accurate, of making the blocks, and he certainly succeeded; and so much so, that I have no hope of anything ever better being discovered, and I am convinced there cannot. At the present time, were we ever so inclined, we could not attempt any alteration. We are, as you know, so much pressed, and especially as the machine your brother-in-law has invented is wholly yet untried. Inventions of this kind are always so different in a model and in actual work.
>
> Believe me, dear Kingdom,
> Yours in great truth,
> Samuel Taylor'

Brunel, having been rejected by Taylor, then obtained an introduction to Bentham, who readily appreciated the merit of Brunel's proposals and on 15th April 1802 recommended to the Secretary of the Admiralty that the machinery should be constructed and installed at Portsmouth Dockyard. This was accepted and the work of building the machinery was given to Maudslay who in collaboration with Brunel had been making working models of several of the machines. These models still exist and are preserved in the National Maritime Museum, Greenwich, which also possesses Brunel's sketchbook[7] containing drawings, dimensions, and other details of the machinery.

Taylor's complacency must have been rudely shattered when in 1803 because of the adoption of Brunel's proposals his contract was cancelled and renewed only on a short-term basis. By 24th March 1805 production by the machinery had reached a level at which it was possible for the Admiralty to discontinue the supply by the contractors[5].

The machines were made in three sets, those for blocks from 7 in to 10 in long were completed first, by the middle of 1803; and payment for them was made through Brunel. This was followed in 1804 by machines for making blocks from 4 in to 7 in long and in 1805 by the third set for blocks from 10 in to 18 in long. For the second and third sets of machines Maudslay was paid directly by the Navy Board and a copy[5] of his account covering deliveries from 1803 to 1807 shows the cost to have been nearly £12,000. Brunel was paid for coach hire and a subsistence allowance of one guinea per day, which was increased by ten shillings when he was in Portsmouth. The basis on which Brunel was remunerated for his invention and for his work over a number of years in supervising the installation of the machinery was proposed at the outset by Bentham in a long letter[3] to the Secretary to the Admiralty. His proposal, which was accepted, was that Brunel should be paid a sum equal to the saving effected in one year by the operation of the machinery. This was computed in 1810, when Brunel was after long delay eventually paid, to be £17,663 19s 0d. Brunel had, however, already reported to Goodrich in a letter[5] dated 3rd September, 1807 that by October 15th the Wood Mill would be able to supply all the blocks required by the Navy.

In these machines the action of the cutters on the material was limited by adjustable stops, formers, and the disposition of the parts. The operator was not required to exercise judgement or to be skilled in the use of tools. The machines moreover worked much more rapidly than could craftsmen blockmakers and produced blocks of uniform quality and standard dimensions. It was claimed that 10 unskilled men with the machines could replace the work of 110 skilled blockmakers. The capital cost was recovered in three years from the saving in the cost of production, so that the extraordinarily long life of the machinery made it an unusually profitable investment.

The block-making machinery later declined in use because with the introduction of steam propulsion the Navy's consumption of blocks decreased and is now only about three per cent of what it was in Brunel's time, and the machinery ultimately ceased production when blocks came to be made differently; the sheave is now usually of metal and the shell is fabricated from small pieces of wood with a metal binding. The internally bound block can be made without special machinery, though a use is still found for the corner saw and the scoring machine in the manufacture of the modern block.

Brunel's best-known achievement in his later years was the building of the first Thames tunnel. He was knighted in 1841 and died in 1849. His portrait painted in 1813 by J. Northcote is reproduced as the frontispiece. Isambard Kingdom Brunel the ship-builder, bridge-builder, and railway engineer was his son.

2 Description of the machinery

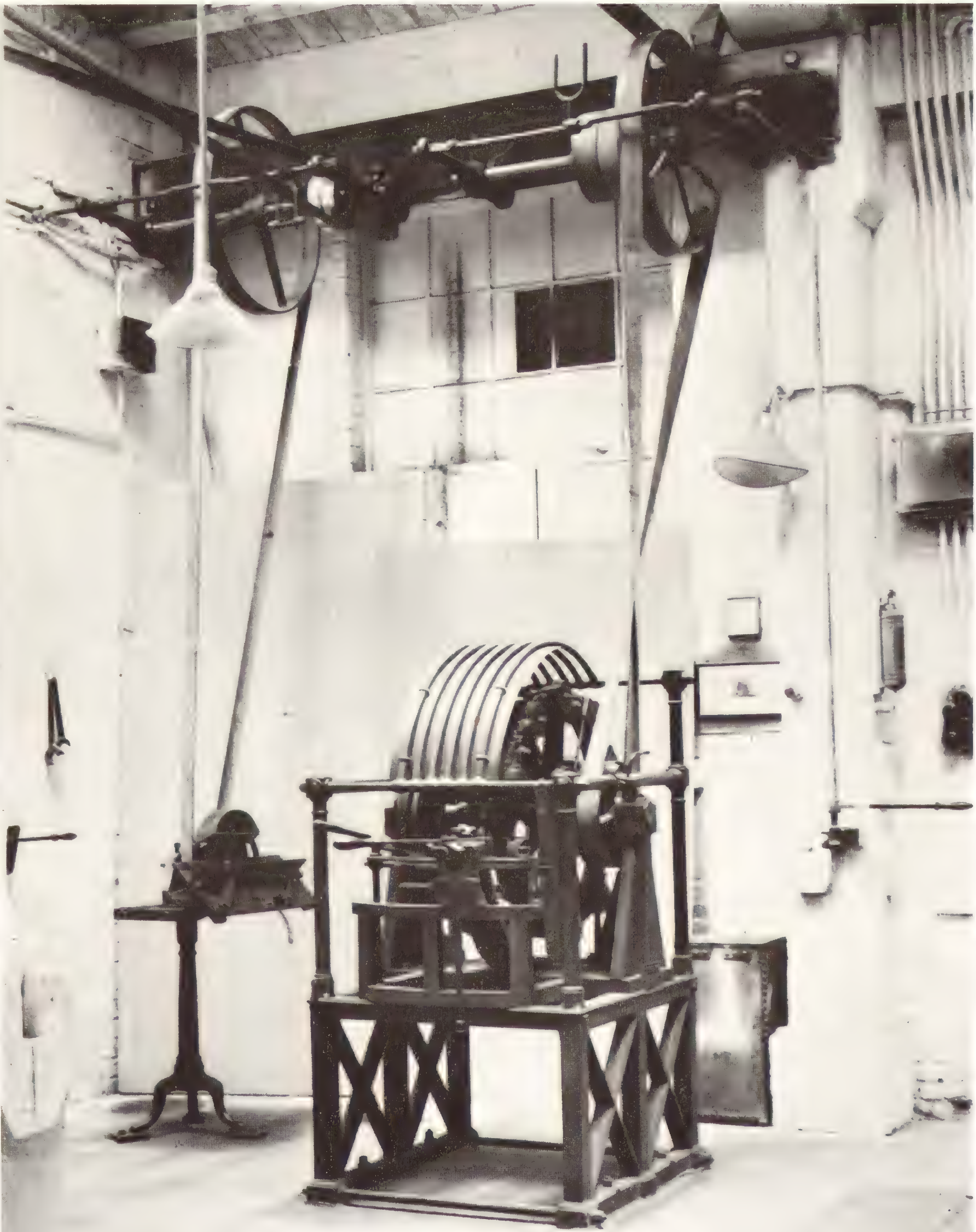
The block-making machinery is stated in Rees's *Cyclopaedia* to comprise 43 machines, but 45 machines are actually described there. The latter number is adopted in the following list which enumerates 22 different sorts of machine.

In some instances there were two or three machines of a kind, but of different sizes, in order to cover the large range of block size. Also at some stages the different rates of working made it necessary to have more than one of certain machines of the same size range in order to maintain a steady flow of components through the plant. The original number was soon added to : thus Brunel in a report[5] dated 3 October, 1805 mentions four boring machines—there were originally three. Another instance of duplication is that the two extant shaping engines (figures 5 and 20) have the same capacity, 4 in to 7 in, but are of slightly different size. There was originally only one machine of this capacity and, as the machine in the Museum conforms more closely to Brunel's design (figure 18), it is probably the earlier of the two.

The terms 'machine' and 'engine' were used interchangeably, but in accordance with modern practice the word 'machine' is used here except for the shaping engine and the broaching engine. 'Engine' is preferred in these cases to avoid a possible misunderstanding arising from the fact that the modern 'shaping machine' and 'broaching machine' are machine tools of entirely different purpose and construction from Brunel's machines.

The machinery was installed on the two floors of a building, which was however not built for the purpose, and power from one of the two steam engines was transmitted by line shafting. A section of this is to be seen in the photograph reproduced as figure 5 which shows the small corner saw and shaping engine. A power-driven vertical shaft, provided with a capstan at the lower end, passed through the centre of the ground-floor room in which the large sawing machines were situated. It was used to draw the logs of timber into the building from the yard. A water supply from a cistern on top of the building was laid on to all parts to deal with any fire that might break out, as the risk in a wood mill was considerable.

The table overleaf lists the 45 machines of the original plant as described in Rees's *Cyclopaedia*, states the number of each type of machine, and indicates where a machine, a model, or a drawing of a machine exists, and the number of the illustration in this monograph.



5 Opposite:
Corner saw and shaping engine in the Block Mills, Portsmouth.
Note the overhead shafting and wall lever

List of the Portsmouth block-making machinery

Machines for preparing the shells

		Figure	*Location of drawings and machines*				
1	Reciprocating saw						
1	Circular saw	9, 10	RC				ScM
4	Circular saw benches						
1	Large reciprocating saw						
3	Boring machines	13	RC	BS	NMM	PDY.*s**	ScM.*m*
3	Mortising machines	*Frontis.* 14, 15, 16	RC	BS	NMM	PDY.*s**	ScM.*m*
3	Corner saws	5, 17	RC	BS	NMM	PDY.*l,s*	
3	Shaping engines	5, 18, 19, 20, 21	RC	BS	NMM	PDY.*s**	ScM.*s*
2	Scoring machines	22, 23, 24	RC	BS	NMM	PDY.*l*	ScM.*s*

Machines for preparing the sheaves

1	Reciprocating saw						
2	Circular saws	25, 26		BS		PDY.*l*	ScM.*s*
2	Rounding saws	27, 28	RC	BS	NMM		ScM.*s*
2	Coaking machines	29	RC	BS	NMM		ScM.*s*
1	Drilling machine						
2	Rivetting hammers	32	RC				
3	Broaching engines	31		BS			
3	Face-turning lathes	30	RC	BS	NMM		

Other machines

3	Pin-turning lathes	33		BS			
1	Polishing machine for pins	34		BS			
1	Lathe for wooden pins						
2	Machines for making dead eyes		RC	BS			
1	Machine for boring made blocks						

Key

RC	denotes machine illustrated in Rees's *Cyclopaedia*
BS	denotes machine illustrated in Brunel's sketchbook
NMM	denotes model in the National Maritime Museum
PDY	denotes machine in the Block Mills, Portsmouth Dockyard
ScM	denotes machine in the Science Museum
l, m, s	denote large, medium, and small machines respectively
*	transferred in 1964 to the Portsmouth Museum

An enumeration of the various processes for making the blocks is given here and followed by a description of the more interesting machines. In the manufacture of the shells the elm tree was first cut into short lengths suitable for the requisite size of block by the cross-cutting circular saw or by the reciprocating saw, the latter being used for logs of large diameter. The lengths of log were then transferred to a sawbench, squared by rip saw, cutting lengthwise, and cut into suitable pieces or scantlings. There was also a large reciprocating saw for cutting up the pieces for very large blocks, known as 'made' blocks. These were up to four feet in length and were fabricated from planking instead of being cut from the solid.

The scantling was then placed in one of the boring machines and two holes drilled as shown in figure 6, the smaller hole to receive the pin on which the sheave would run, and the larger hole to provide a start for the mortise chisel. More holes would of course be required for blocks containing two or more sheaves.

The hole was then enlarged to a slot for the sheave by the mortising machine. After cutting off the corners by means of a corner-sawing machine the shells were formed ten at a time to the required figure on a shaping engine. The shell was then placed on a scoring machine to cut the scores for the reception of a rope. Finally the shell was passed over a special plane, which fitted the mortise, so as to remove any roughness, and the exterior of the shell was polished by hand.

The sheaves (figure 7) were made from slices of lignum vitae cut from a log by one of the converting machines which comprised two circular saws and for the largest logs a reciprocating saw. Then in a rounding machine or rounding saw the slice was simultaneously made circular and a hole for the pin was bored. Three recesses were then milled by means of the coaking machine in each side of the disc to accommodate the ears of the coak. The coaks were cast from bell metal and had an internal spiral groove to retain grease for lubrication. Holes were then drilled through the ears of the coaks and the sheave. Wire pins were inserted and rivetted down. The coaks were then bored out in a broaching engine smooth, cylindrical, and concentric with the rim. Finally the sheave was placed in a face-turning lathe in which the faces were turned smooth and at the same time a groove cut in the edge for the rope.

An iron pin, as shown in figure 8 was one of the components that went to make the finished block. It was forged cylindrical except for a short length which was left square to bite into the shell so that it would stay fast without rotating. It was then turned smooth in the pin-turning lathe and burnished in the pin-polishing machine. Finally the shell, sheave, and pin were assembled by hand.

Blocks intended for use in a powder magazine were fitted with wooden pins to avoid the risk of a spark arising from the use of iron. These pins were turned on a simple lathe known as a whisket.

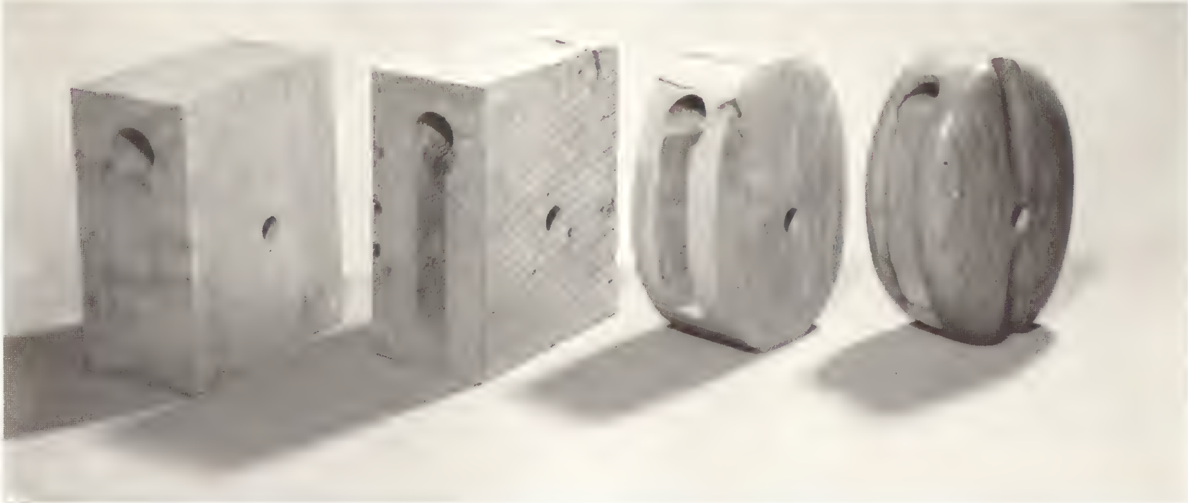
There were also machines for turning and boring dead eyes–blocks without sheaves for the attachment of rigging–and a machine for boring the made blocks.

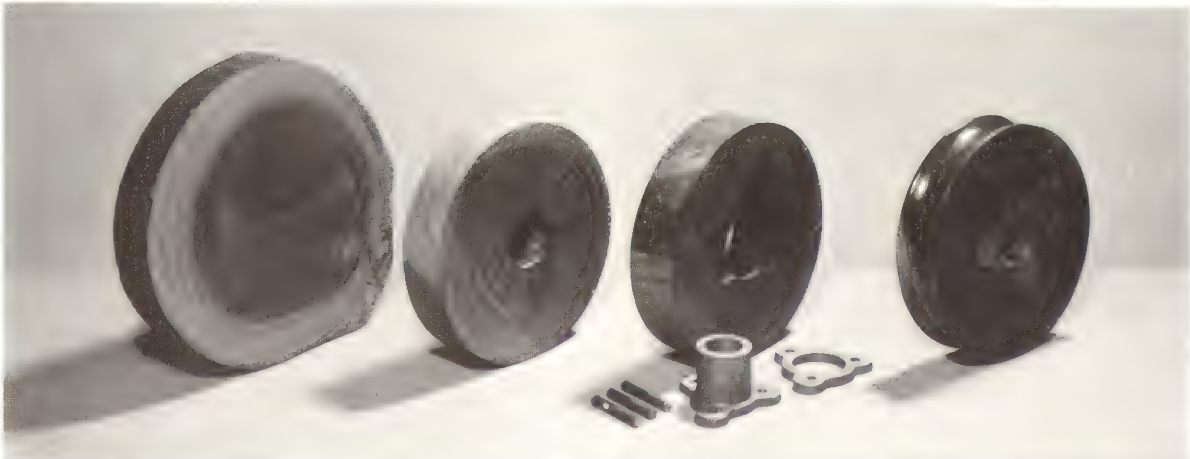
Opposite:
Stages in the
manufacture
of a block

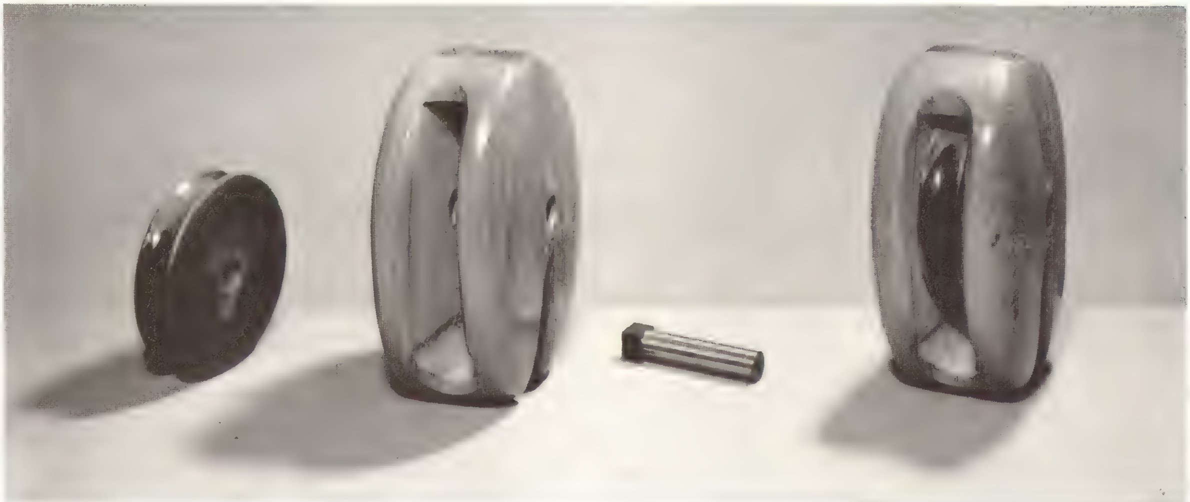
6 The shell

7 The sheave

8 Assembly







Considering firstly the machinery used for making the shells, the elm logs were cut up by the cross-cutting circular saw illustrated in figures 9 and 10, which was known from its method of working as the pendulum saw. The saw spindle is supported at the end of a frame HH, which is pivoted at the end of the frame MM, which is balanced about pivots in the fixed frame NN. The elevation of M is controlled by the rods QQ, which bear racks meshing with pinions turned by the handle W. Similarly the handle V can be used to adjust through the rack rods XX the inclination of frame H. So, by manipulating the handles V and W, it is possible to cut the log first on one side, then from above, and then from the other side, so that a log of greater diameter can be cut than would be possible with a fixed saw. The log is drawn, by rocking the winch handle E, to an adjustable stop *f* to measure off the length for cutting.

In the boring machine (figure 13) the operator, moving the handles in succession, bored the squared piece of wood with holes for the pin and for the mortise chisel. The settings are of course adjustable. The most interesting feature, however, is that the screw press which clamps the blocks of wood in position impresses on their ends indentations such as those illustrated in figures 11 and 12. These serve to locate the shell in the subsequent mortising machine and shaping engine.

The mortising machine was the first of its kind and the slotter for cutting keyways in wheels derives from it. The machine for medium-range blocks is illustrated in Brunel's sketchbook (figure 14), the actual machine in figure 15, and an explanatory drawing in figure 16. The model of the machine appears in the background of Brunel's portrait (frontispiece).

This machine, once set in motion, mortised two blocks at a time or a two-sheaved block, without attention. As shown in figure 16 the chisels A in the sliding frame K receive a reciprocating motion from the crank *d* at the end of the rotating shaft E. With each revolution the cam *h* causes the ratchet wheel M to turn by one tooth and to advance the lead screw L which is threaded through it. This rotation of the screw advances the carriage D containing the blocks, so that the chisels at each successive descent cut $\frac{1}{24}$ in further along the block. When the mortise has been enlarged to the required extent, the weighted end *o* of the lever *i* which has hitherto been supported by the carriage, drops down. This action disengages the pawl from the ratchet wheel and stops the traverse. At the working speed of 400 strokes per minute the chisels cannot be distinctly seen and the mortises are observed to lengthen without evident cause.

The operator can disengage the machine from the drive and quickly bring it to rest for resetting without destroying the momentum of the flywheel, by means of the conical clutch assembly shown in figure 16, sub figure 1. Movement of the hand lever will bring the conical wheel R on the shaft into contact either with the driving pulley H keyed to the flywheel or with the brake drum W. This is believed to be the first instance of the use of a cone clutch.

9 Opposite:
The pendulum saw, from Rees's *Cyclopaedia*

MACHINERY.

PLATE I.

BLOCK MACHINERY at PORTSMOUTH.

Sawing Machine.

Elevations

Fig. 1.

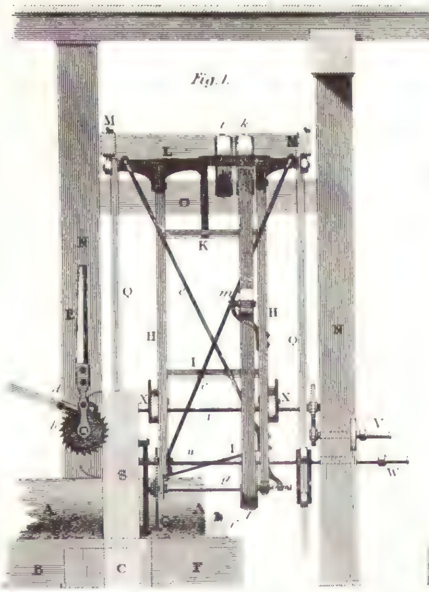


Fig. 2.

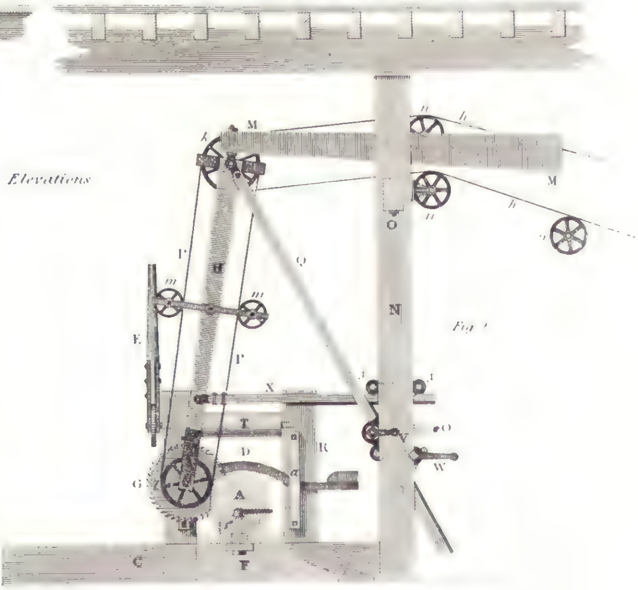


Fig. 3.

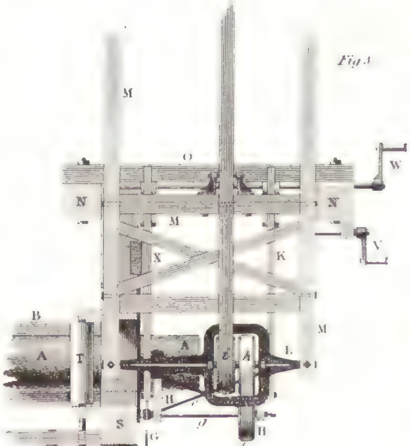
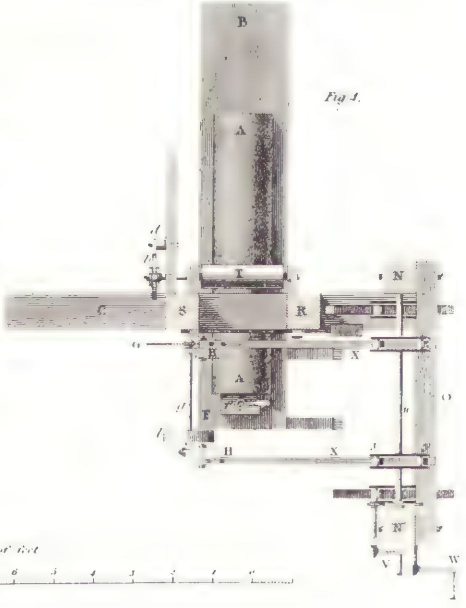


Fig. 4.



Scale of Feet

12 11 10 9 8 7 6 5 4 3 2 1 0

J. Farey del.ⁿ

Published as the Act directs 1812 by Longman Hurst Rees Orme & Brown Paternoster Row.

Engraved by Wilson Lowry.

The corner saw used for cutting the smallest range of blocks appears in figure 17. The block was placed upon the inclined table and against the ledge set in a position appropriate to the size of block. Thus supported the block was presented to the circular saw which cut away the angle as required. The ledge is fitted with connecting bars in the style of a parallel ruler, so that it remains parallel to the saw when the distance is altered.

The small shaping engine is illustrated in figures 18 to 21. It consists of a double wheel, called its chuck, in which ten block shells are revolved together and intercepted by a gouge. The gouge is fixed to a slider that carries a roller, which is kept in contact with the former N by manipulation of the handles *m* and R. In this way the gouge is made to shape the outside of the shells to the required pattern. After completing one side the shells are simultaneously indexed through 90°, so that the next side may be cut with the roller in contact with another former. The shell holders are all connected through worm and bevel gearing with a crown wheel on the axle, so that they can be rotated together. To bring this about the stop Q is moved up to engage a pin projecting from the circumference of the crown wheel O, which is fitted on the main axle, but not keyed to it. If now with the crown wheel held stationary the chuck is pulled round four times by hand, the blocks will be rotated through a quarter of a turn.

The scoring machine by which the shells were scored two at a time is illustrated in figures 22 to 24. The cutters A and B are mounted on a carriage, which pivots about the axis F and is guided by keeping the cover of the pulley D in contact with the former L, which is suitably shaped. The shell holders are mounted on a table G which is rotatable through 180°, so that both ends of the blocks may be scored.

In the manufacture of the sheaves the lignum vitae is first sawn into slices by means of the saw illustrated in figures 25 and 26. The larger saw still gives satisfactory service at Portsmouth. The operator turns with his left hand a handle which communicates through gearing in the base of the machine with the log holder and causes it to rotate, while with his right hand he swings the saw into the log. This arrangement enables a log of diameter not greatly less than that of the saw to be sawn and makes the cut clean and parallel.

The rounding saw, crown saw, or trepan saw, illustrated in figures 27 and 28 simultaneously cuts the lignum vitae slice circular and bores a hole through it. The wood is held between the cup *h* and the tube E through which the drill K passes. The arrangement enables the saw A and the drill K to be advanced together, but to be driven at the necessarily different speeds by their pulleys D and I.

The coaking machine, illustrated in figure 29, is a milling machine designed for cutting the recesses in the sheave to receive the ears of the coak. The sheave is held internally by an expanding arbor made of three segments of a ring, which are forced apart by drawing into them a tapered plug. This useful device was generally regarded as an invention of Brunel, though in fact he had been anticipated in it by

Leonardo da Vinci. The sheave is secured below the cutter spindle to a table, which is moved away from the axis with the result that a recess is milled in the sheave to a depth and extent determined by stops. The table is equipped with an indexing mechanism by which the sheave is rotated through 120° for the next cut.

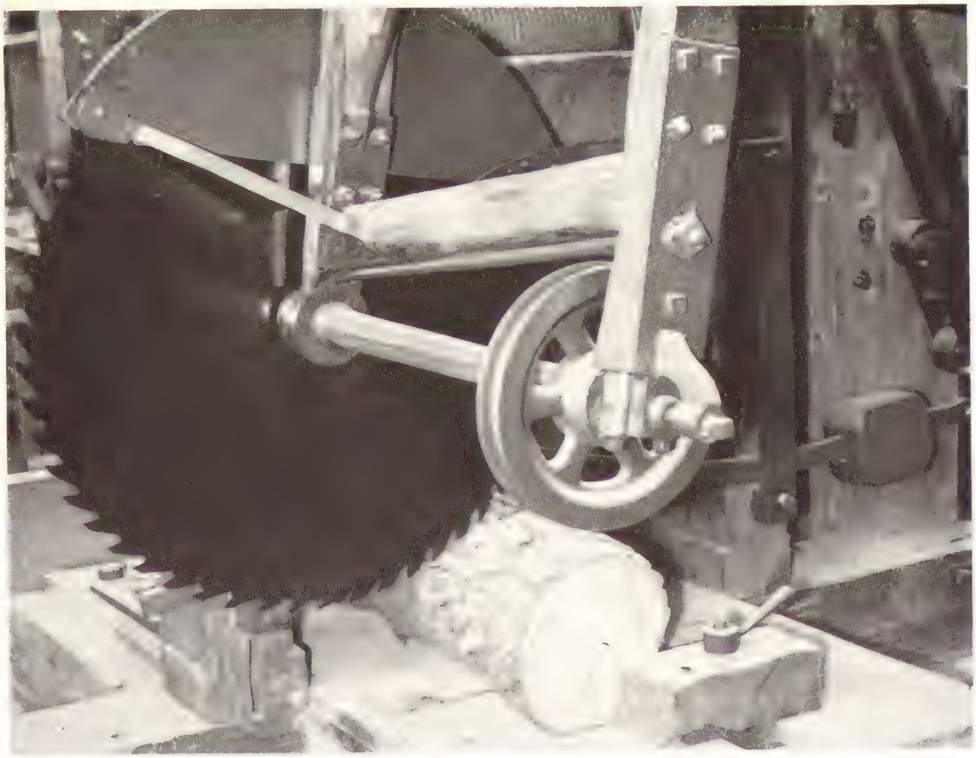
The power-driven rivetting hammer for securing together the two parts of the coak is illustrated in figure 32. The hammer is lifted by the cogs of the wheel D at the rate of four hundred times per minute and falls by its own weight aided by the spring I. The workman can control the force of the blow by means of a treadle attached to a rope passing round wheel N, which rotates the cam M and adjusts the compression of the spring.

After the coak had been drilled and rivetted to the sheave the interior surface of the centre hole was made smooth and cylindrical on the broaching engine shown in figure 31. The sheave is fixed on a chuck at the upper end of a vertical spindle which is hollow for a considerable depth. The borer is a cylindrical rod which fits exactly into the hole and carries a small steel tooth. The sheave is centred by causing the borer to pass through it into the spindle, after which it is clamped down. The chuck is rotated and the boring bar is advanced through the sheave to enlarge the hole.

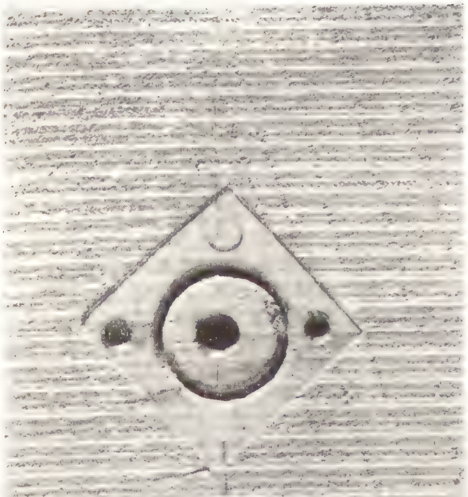
The sheaves were completed on the face-turning lathe, the model of which is reproduced in figure 30. The cutting tool for facing is mounted on a slide rest and the cross feed obtained via the pulleys through a worm on the mandrel. The feed was automatically disengaged at the end of the traverse so that the operator could give his full attention to turning the groove in the edge of the sheave while face turning was in progress, as soon as he had the spindle running at the proper speed for turning wood. The facing cut was started at the centre of the sheave at half speed, which was suitable for turning the metal coak; but when the tool reached the edge of the coak, the workman had to shift the driving strap from one wheel to an adjacent wheel running at double speed.

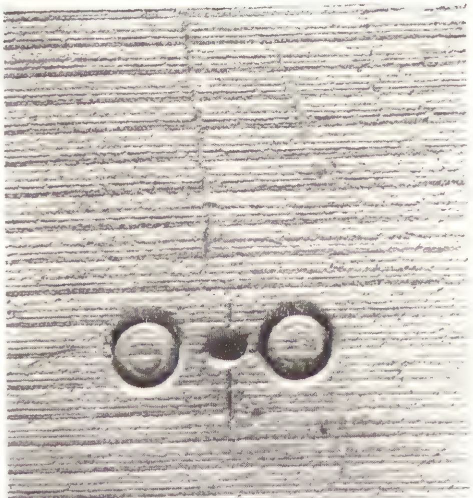
The iron pins were turned on the self-acting slide lathe illustrated in figure 33. This was equipped with automatic trip gear and the feed was stopped by disengaging the worm from its wheel.

The pins were finally burnished in the pin polishing machine illustrated in figure 34, which shows three machines mounted side by side in one frame. The pin was attached to the lower end of a screw and then drawn while rotated through three steel dies disposed in a triangle about the pin and immersed in oil. The die box communicated with a larger vessel to render the oil level virtually independent of the position of the pin. The screw passed through a split nut at the top of the machine, which was closed when the machine was working, so that the screw rose as it turned; but for rapid resetting the nut could be opened to give the screw free movement. The use of the split nut as a means of engaging the lead-screw of a lathe to make the carriage traverse at will was patented by Whitworth in 1835, but the principle was evidently anticipated in this machine.



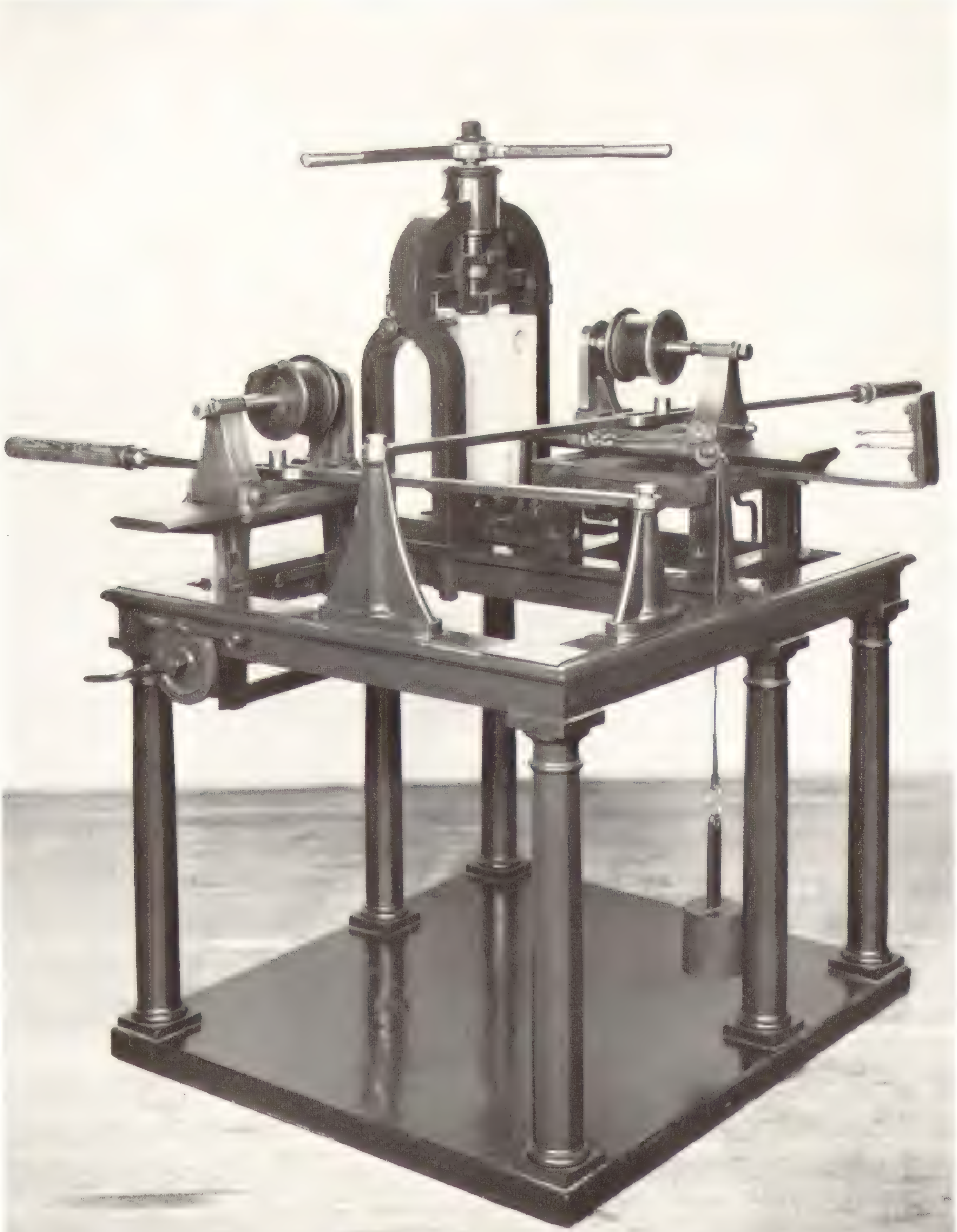
10 Pendulum saw detail (*in the Science Museum Collections*)

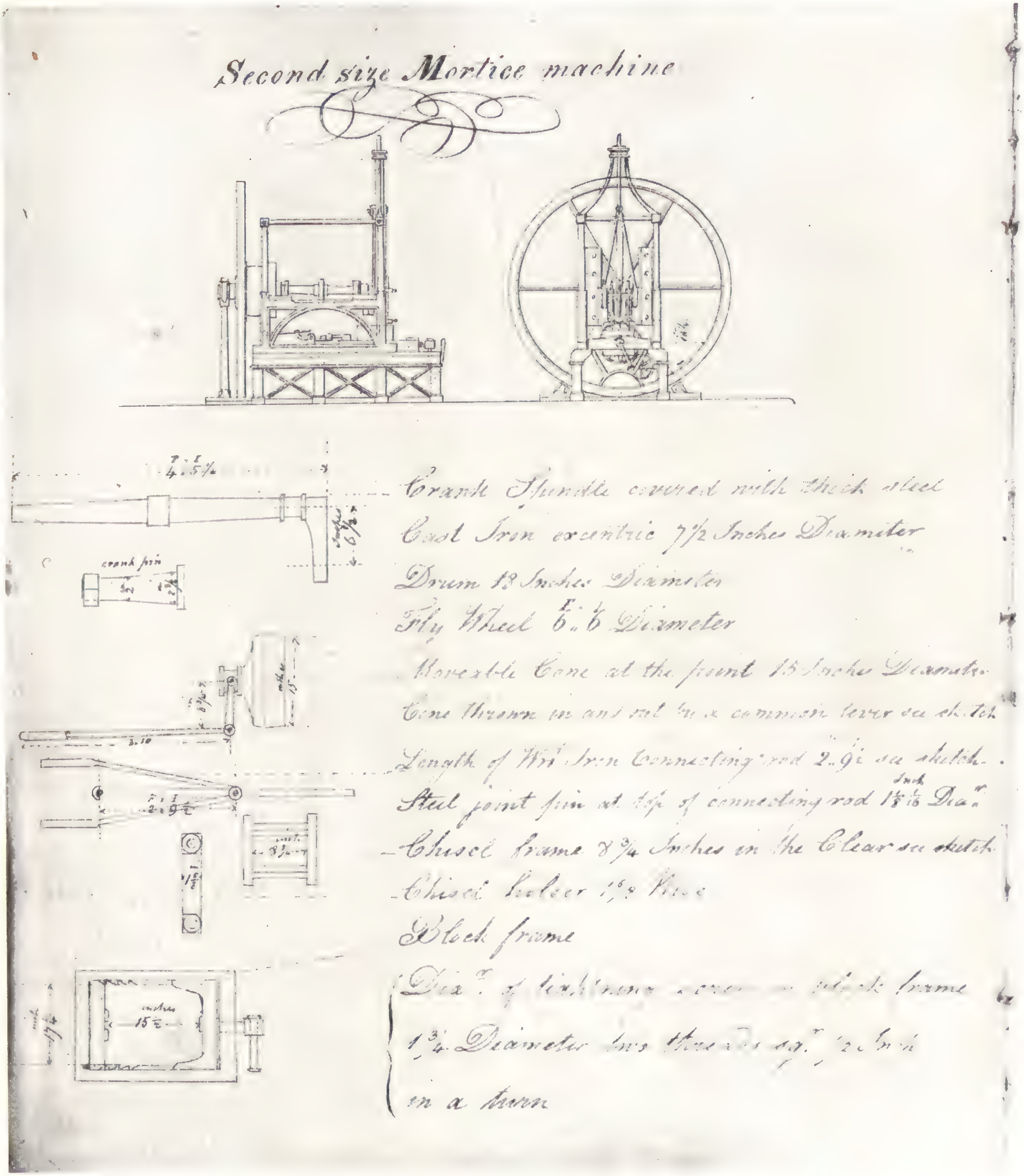




11, 12 Details of shells showing locating marks

13 Opposite: Boring machine (*in the Science Museum Collections*)





Second size Mortice machine

Crank Spindle covered with thick steel

Cast Iron excentric 7½ Inches Diameter

Drum 18 Inches Diameter

Fly Wheel $6^{F}.6^{I}$ Diameter

Moveable Cone at the point 15 Inches Diameter

Cone thrown in and out by a common lever see sketch

Length of Wrt Iron Connecting rod 2.9½ see sketch

Steel joint pin at top of connecting rod 1 3/16 Inch Diar

Chisel frame 8¾ Inches in the Clear see sketch

Chisel bolser 1⅝ Ins

Block frame

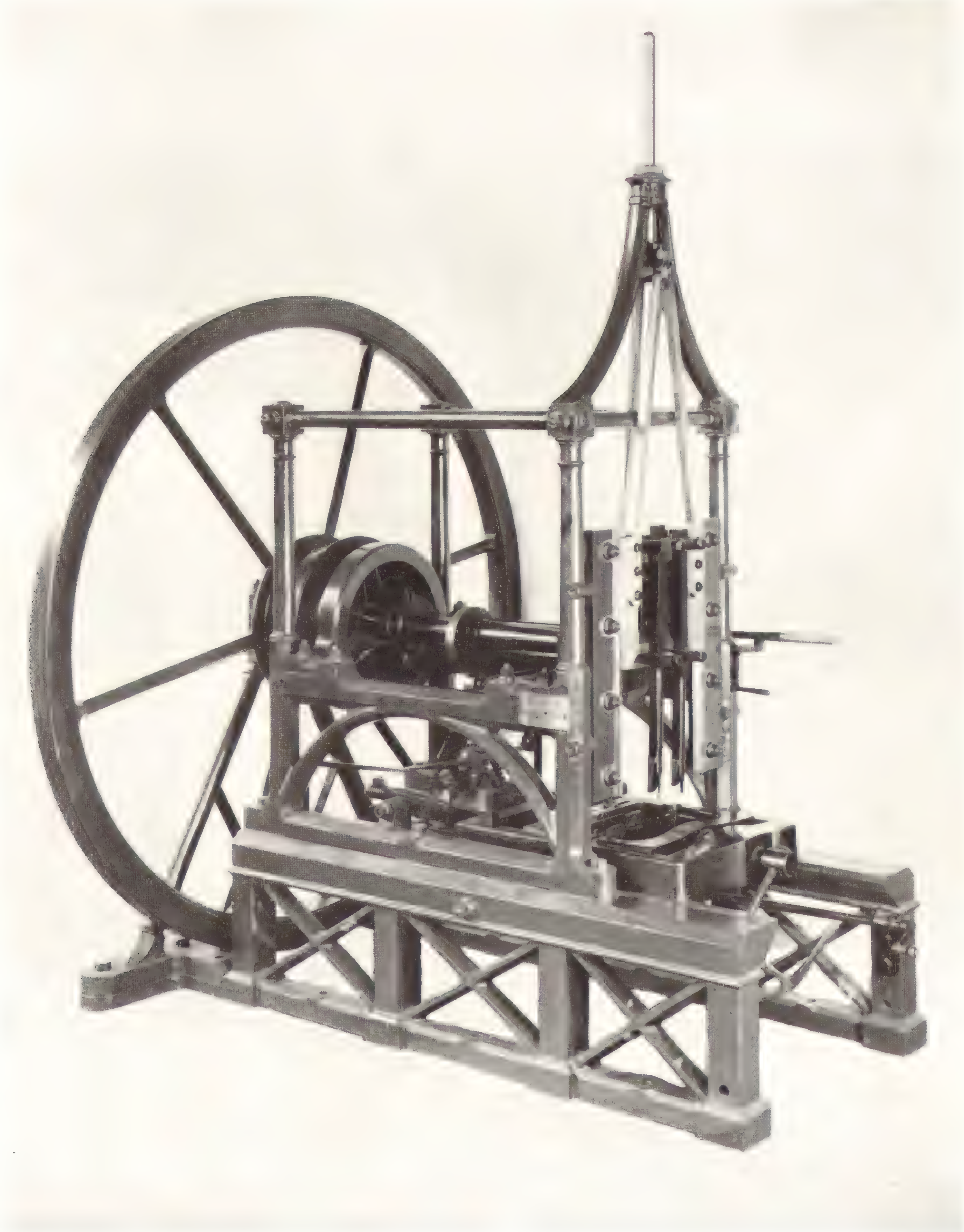
Diar. of tightening screw in block frame

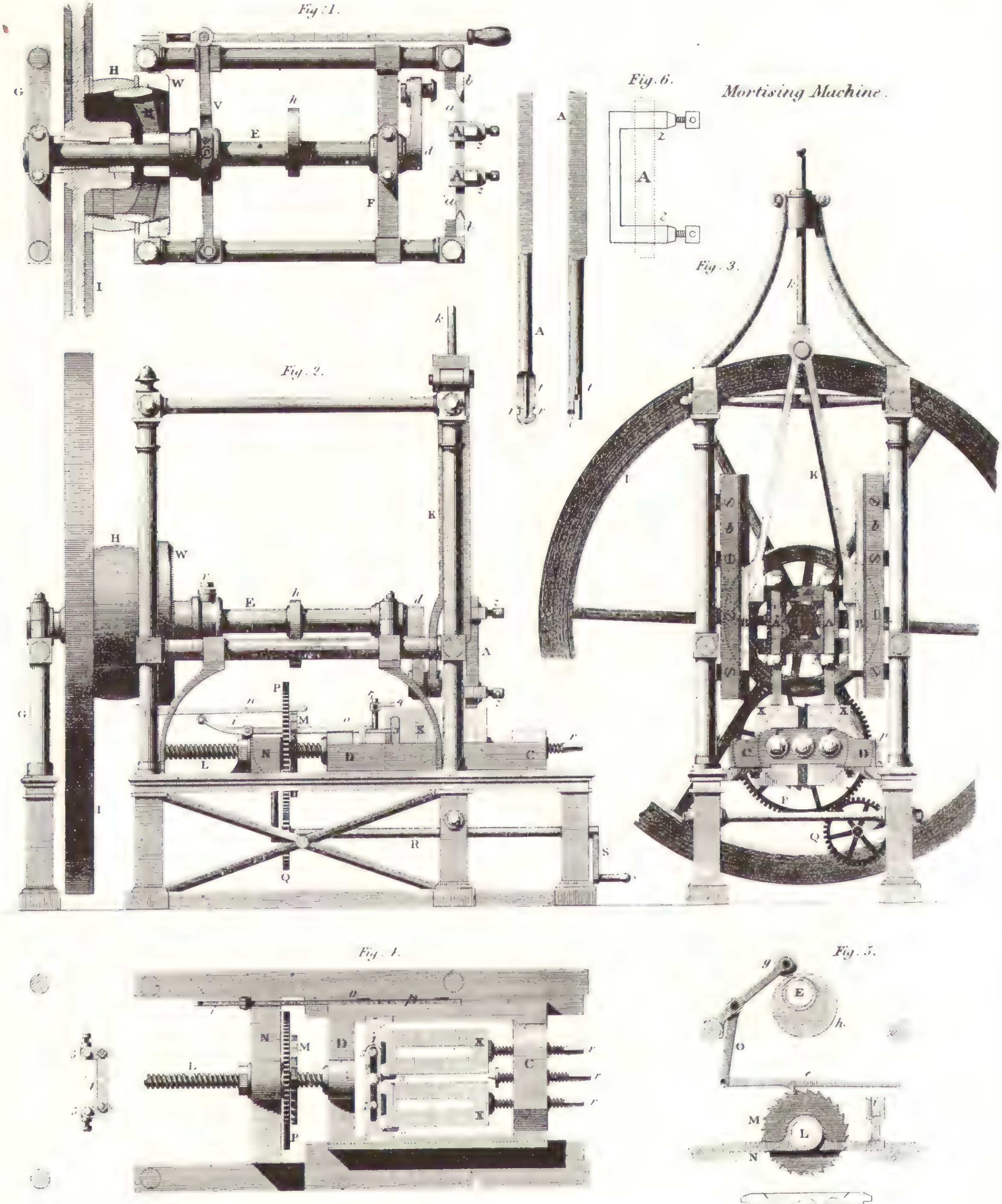
1¾ Diameter two threads sqr. ½ Inch

in a turn

14 Mortising machine, from Brunel's sketchbook, the first of two pages, very slightly reduced (*in the National Maritime Museum*)

15 Opposite: Mortising machine (*in the Science Museum Collections*)





Mortising Machine.

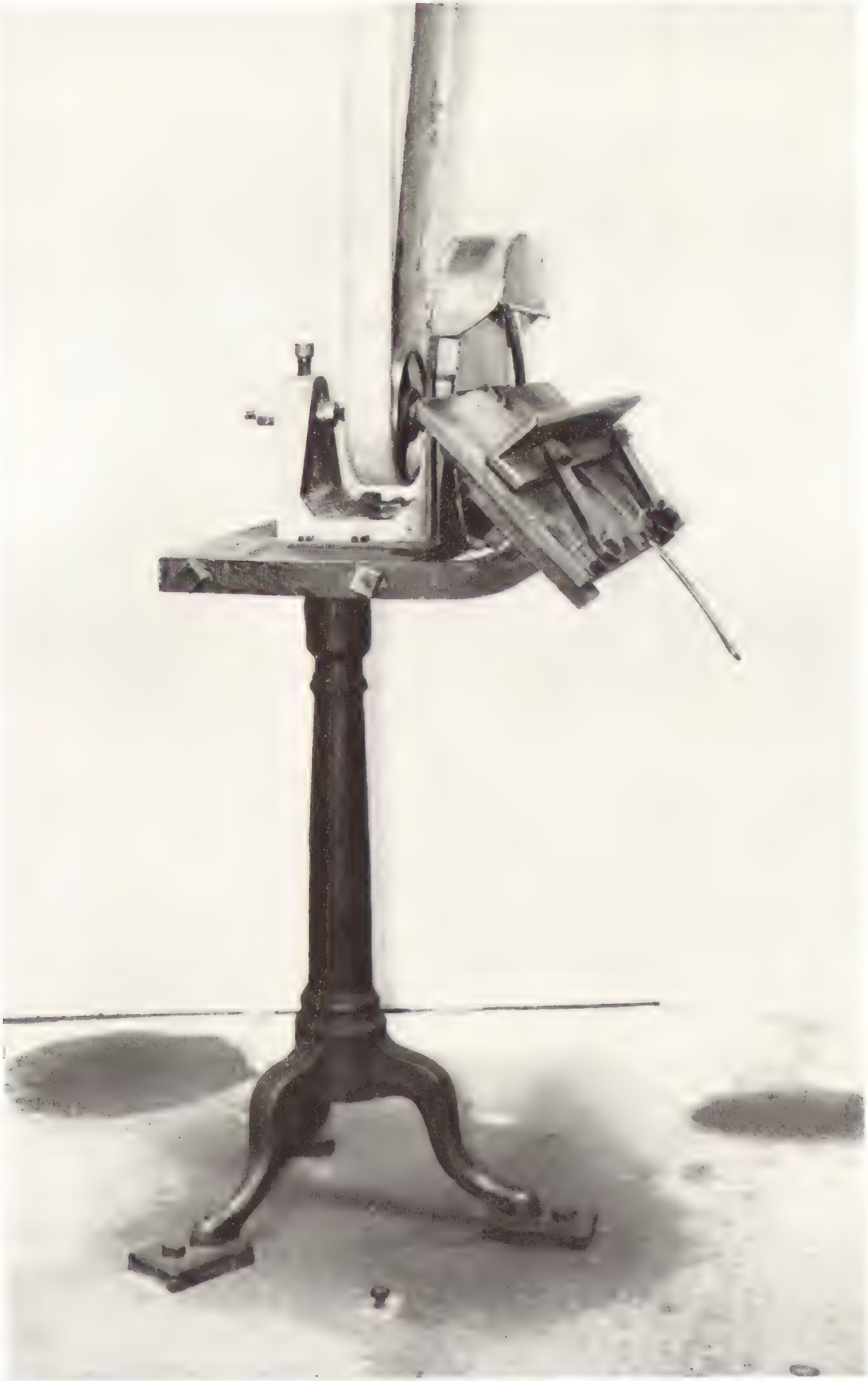
J. Farey del.

Published as the Act directs, 1816, by Longman Hurst, Rees, Orme & Brown, Paternoster Row.

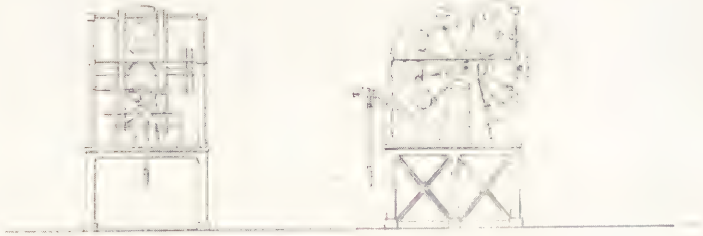
Lowry Sc.

16 Opposite:
Mortising machine
from Rees's
Cyclopaedia

17 Corner saw
(*in the Block
Mills, Portsmouth*)



Small Shaping machine.



Braſs Chucks 28 Inches Diameter at the centre of the blocks

Braſs bevel wheel 9 inches Dia at pitch line 30 teeth [illegible] pitch

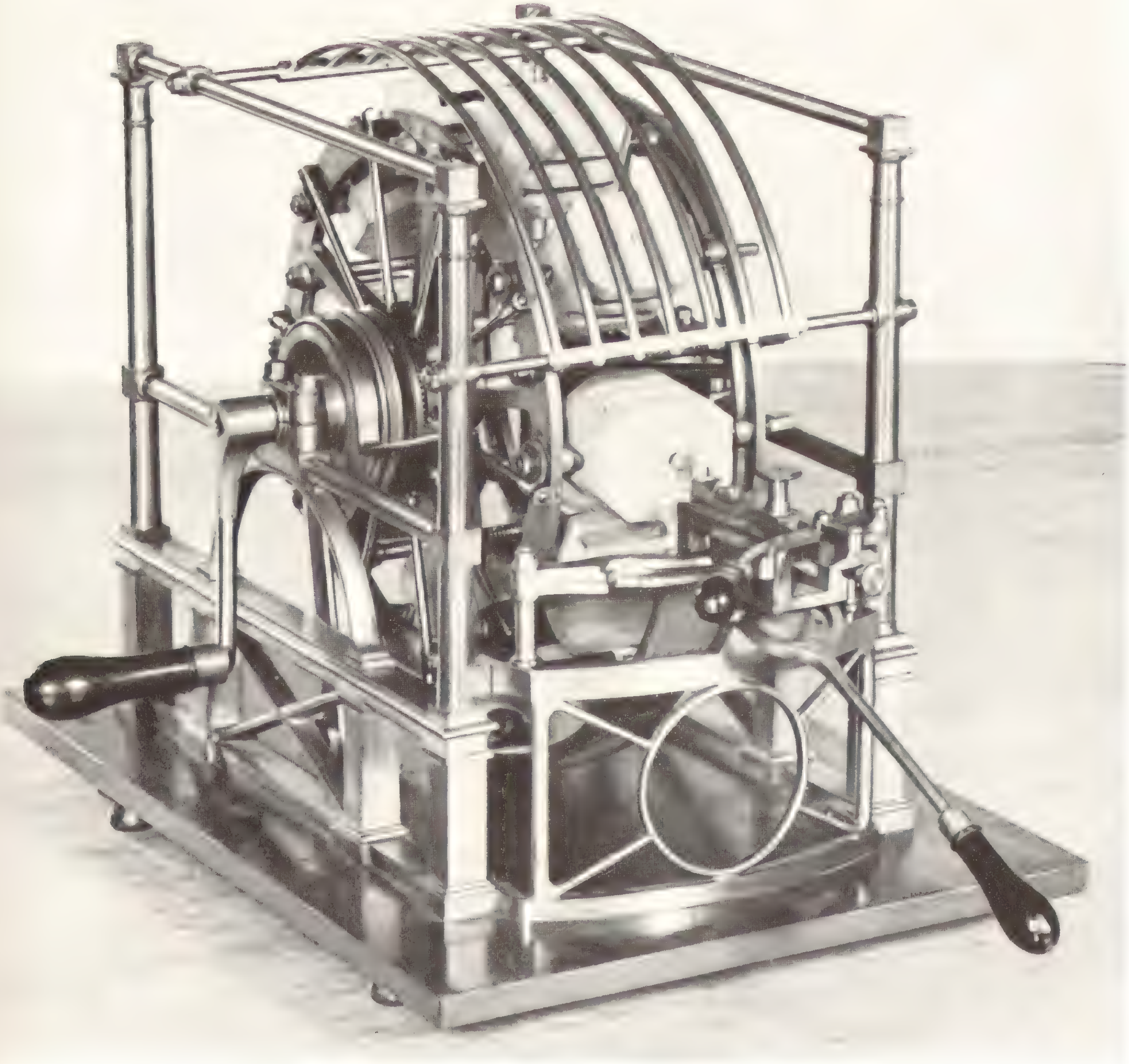
Braſs bevel pinion 2½ inches Dia. 16 teeth ⅝ inch pitch

Braſs Worm wheels 3.37 inches pitch line 24 teeth

Steel worms ¾ inch at pitch line, the worm has 6.3 turns in 1 inch, the [illegible] of the thread of the worm [illegible] inch

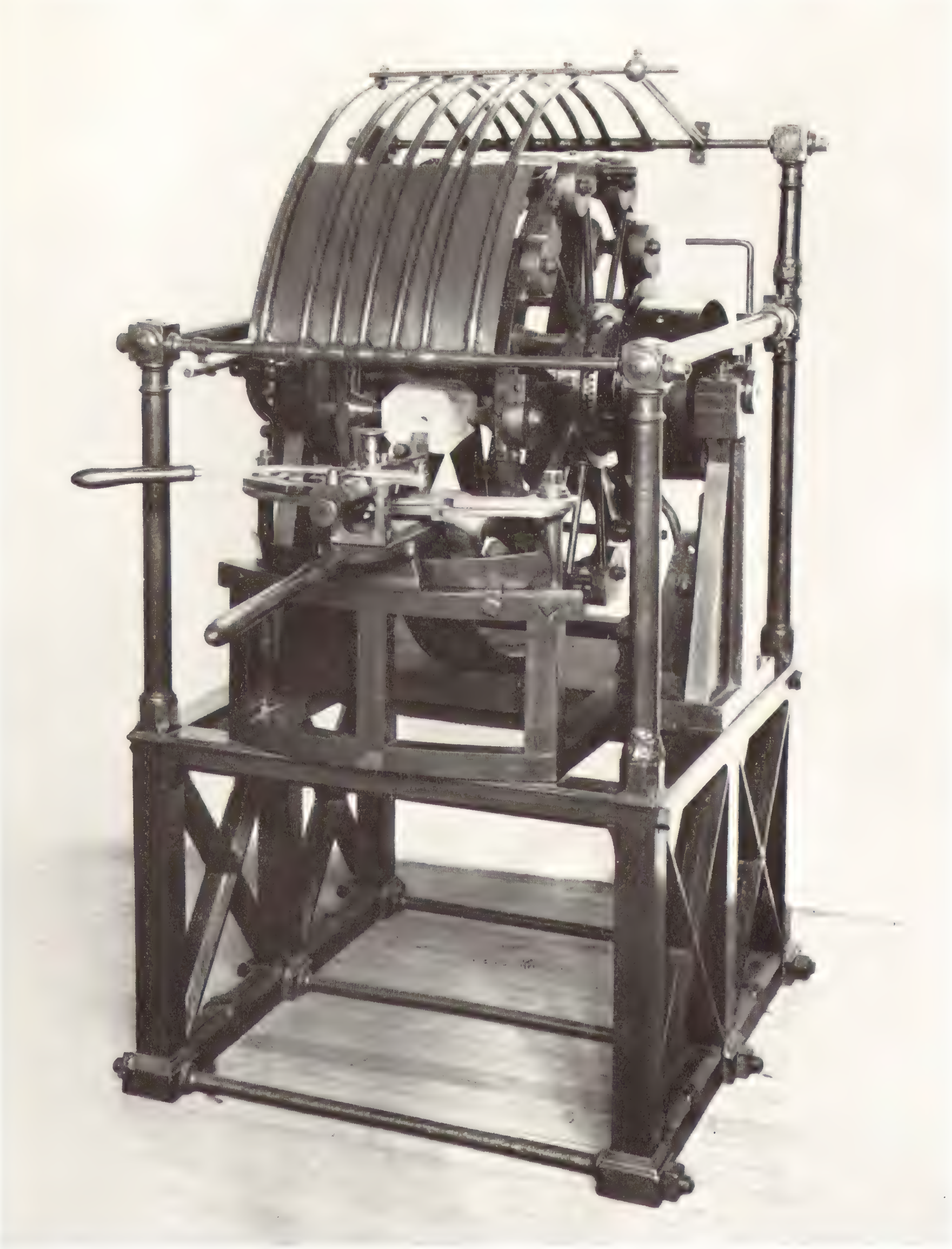
[illegible]

[illegible] the wheel [illegible] the blocks [illegible] turn



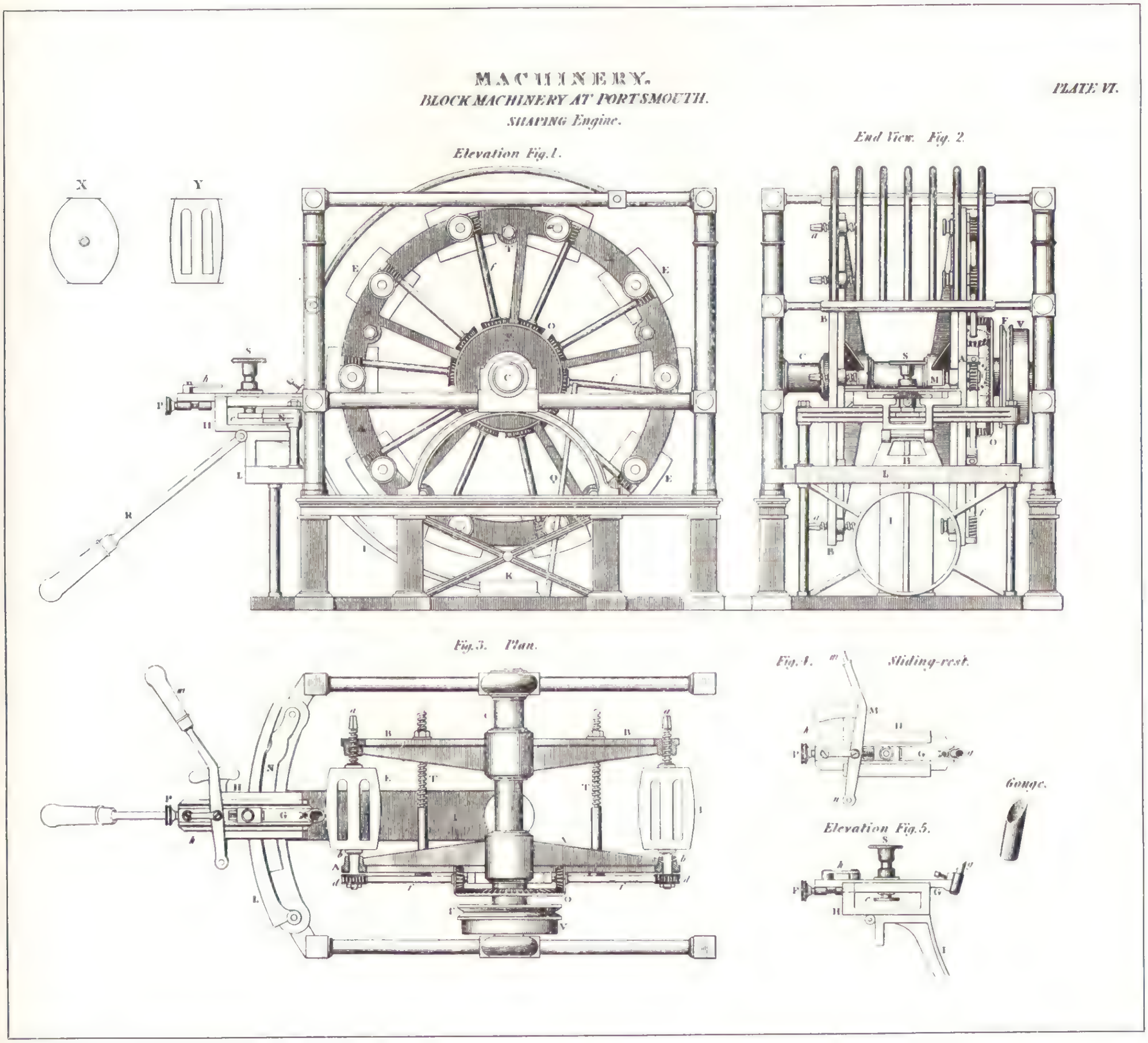
19 Shaping engine—
original model
(*in the National Maritime Museum*)

18 Opposite:
Shaping engine, from Brunel's sketchbook, the first of two pages, very slightly reduced



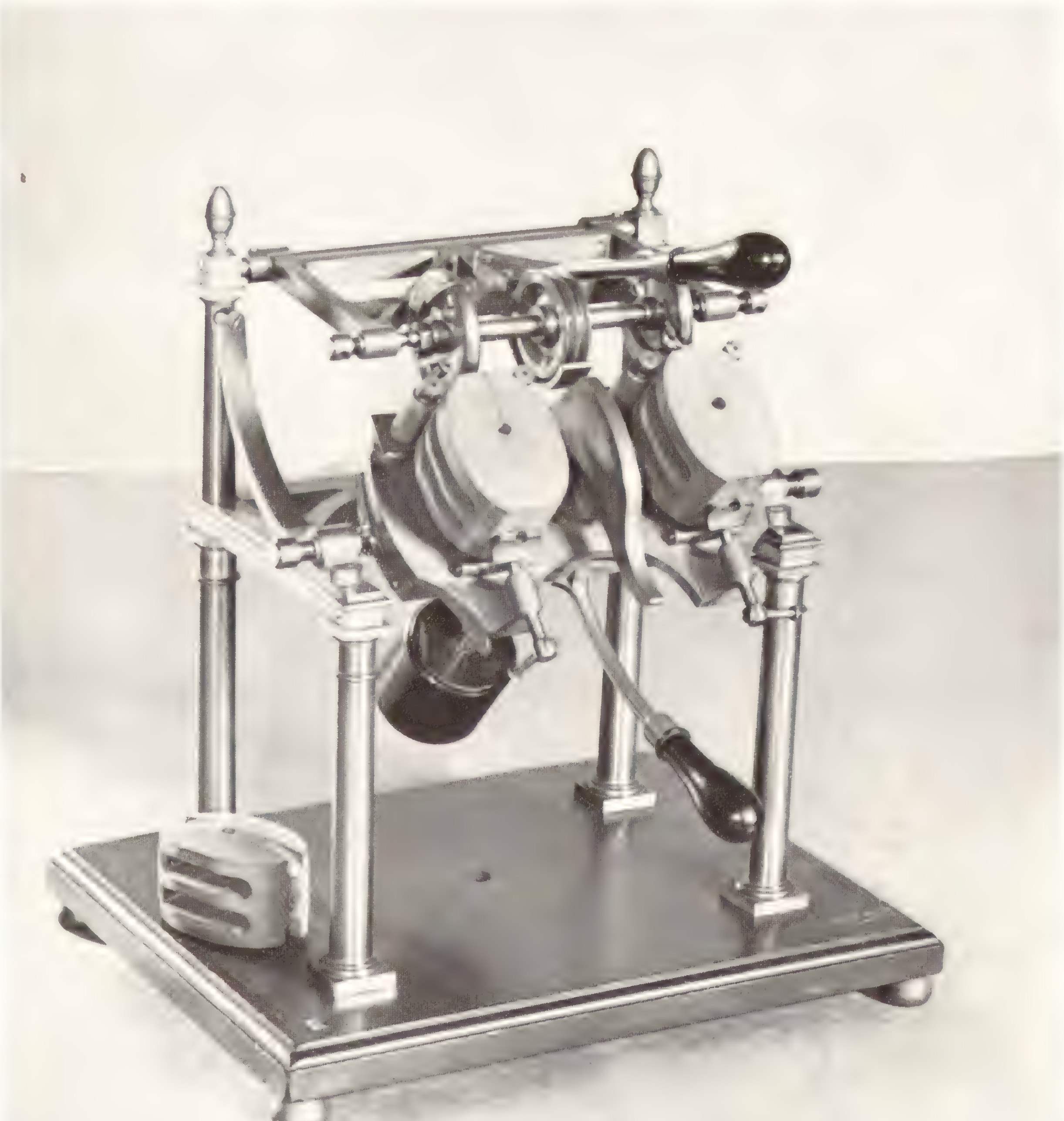
20 Opposite:
Shaping engine
(*in the Science Museum Collections*)

21 Shaping engine, from Rees's *Cyclopaedia*



22 Scoring machine—
original model
(*in the National Maritime Museum*)

23 Opposite:
Scoring machine,
from Rees's
Cyclopaedia



Invented by Mr. Brunel.

Fig. 1.

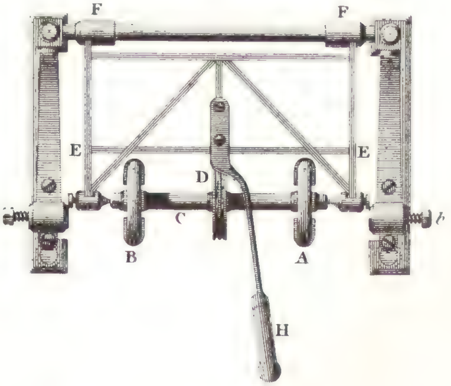


Fig. 2.

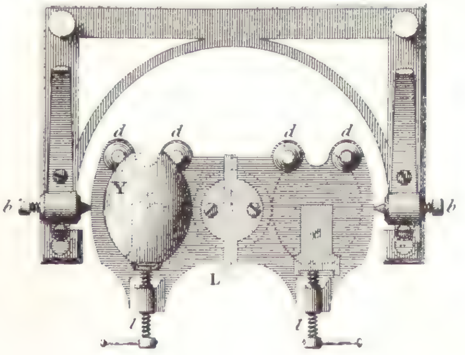
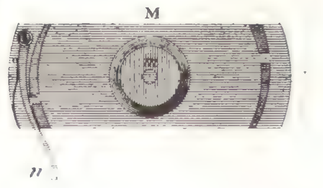


Fig. 3.



SCORING Engine

Fig. 4.

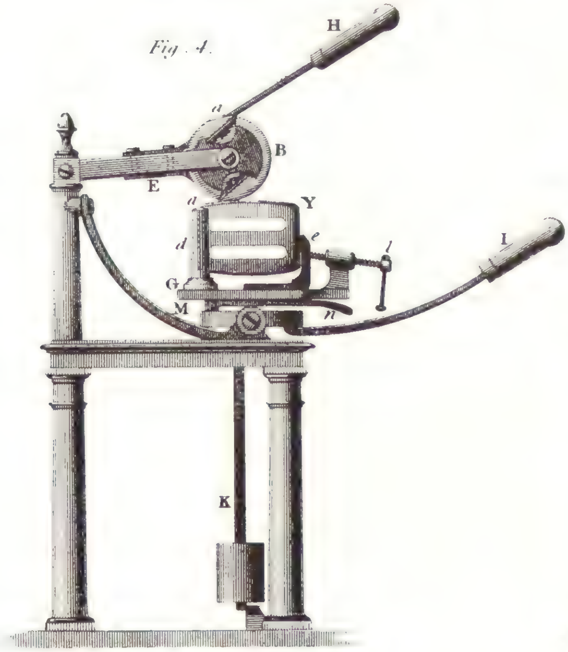
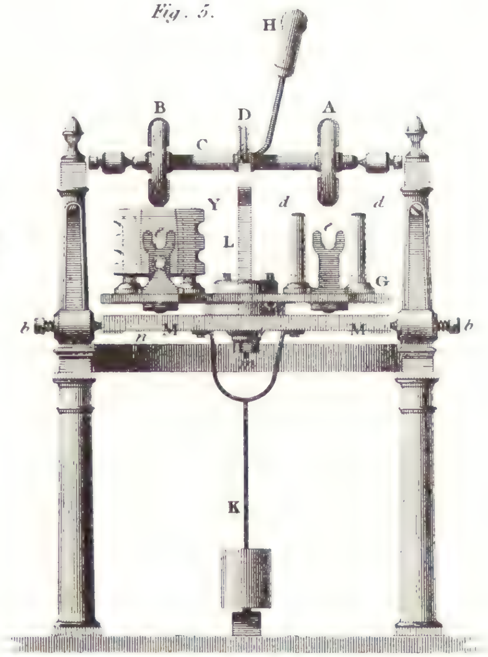
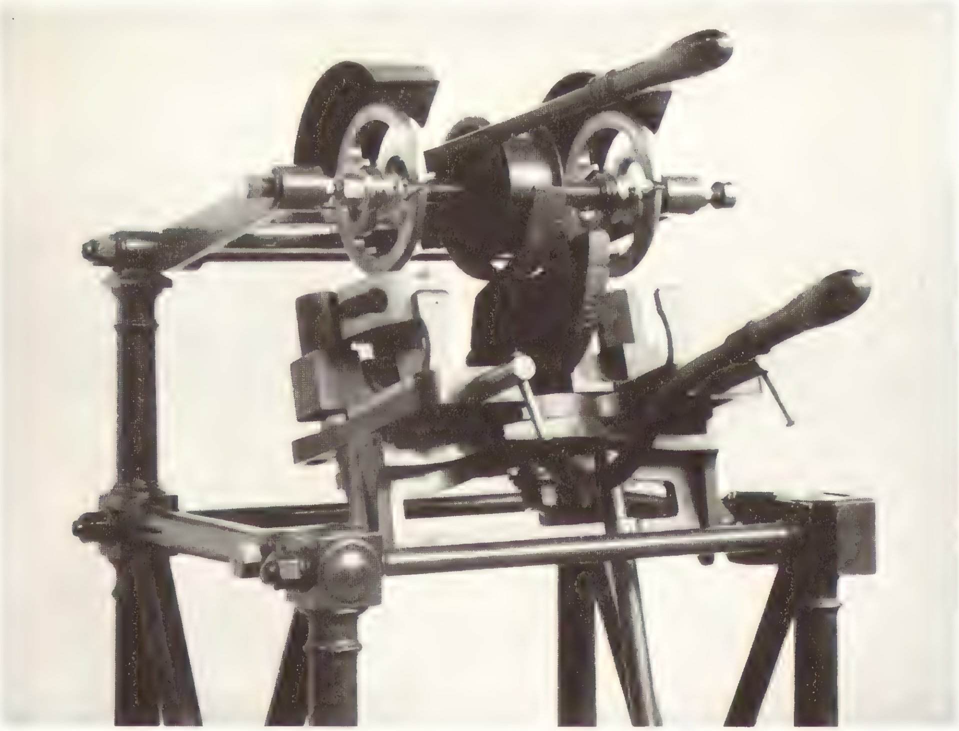
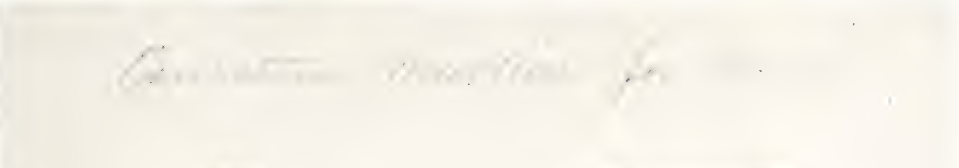


Fig. 5.



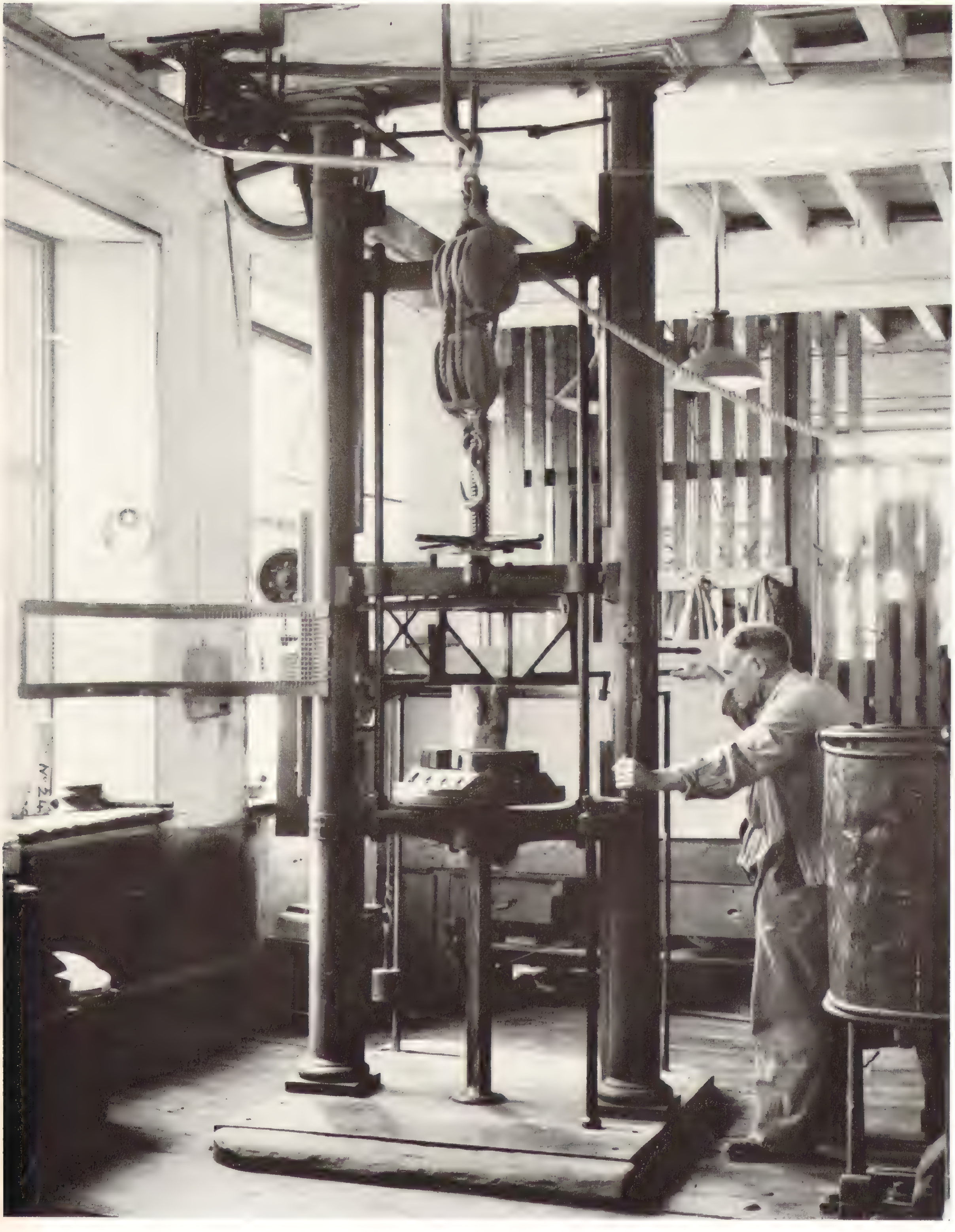


24 Scoring machine (*in the Science Museum Collections*)



25 Below: Lignum vitae saw from Brunel's sketchbook, original size (*in the National Maritime Museum*)

26 Opposite: Lignum vitae saw in use at the Block Mills, Portsmouth, in 1963. Note the set of original Brunel-made blocks for hoisting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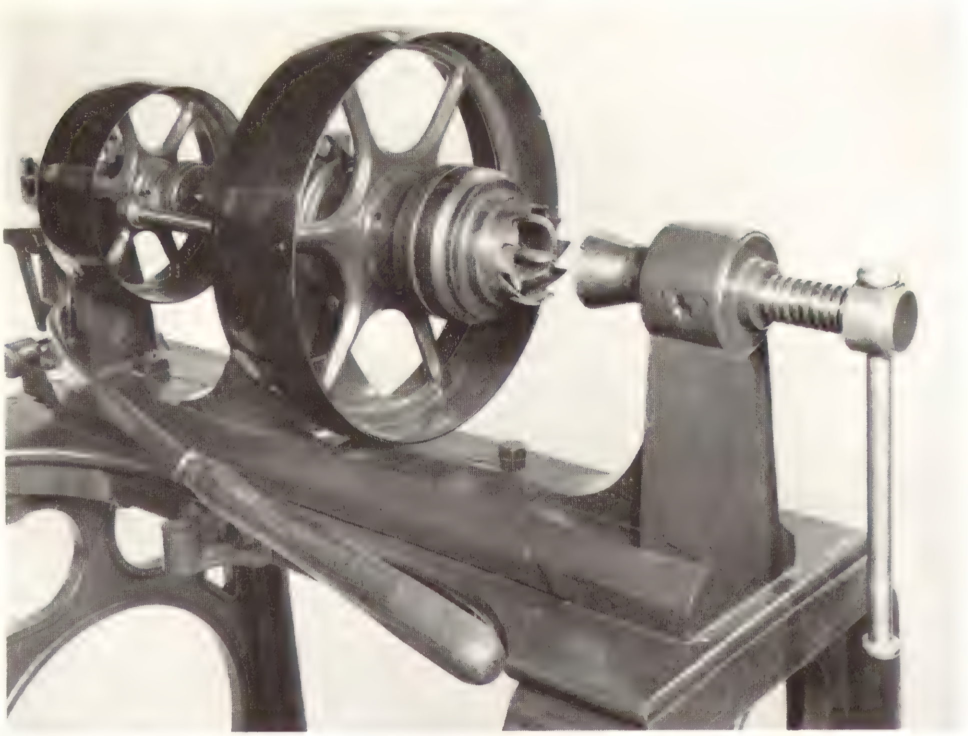
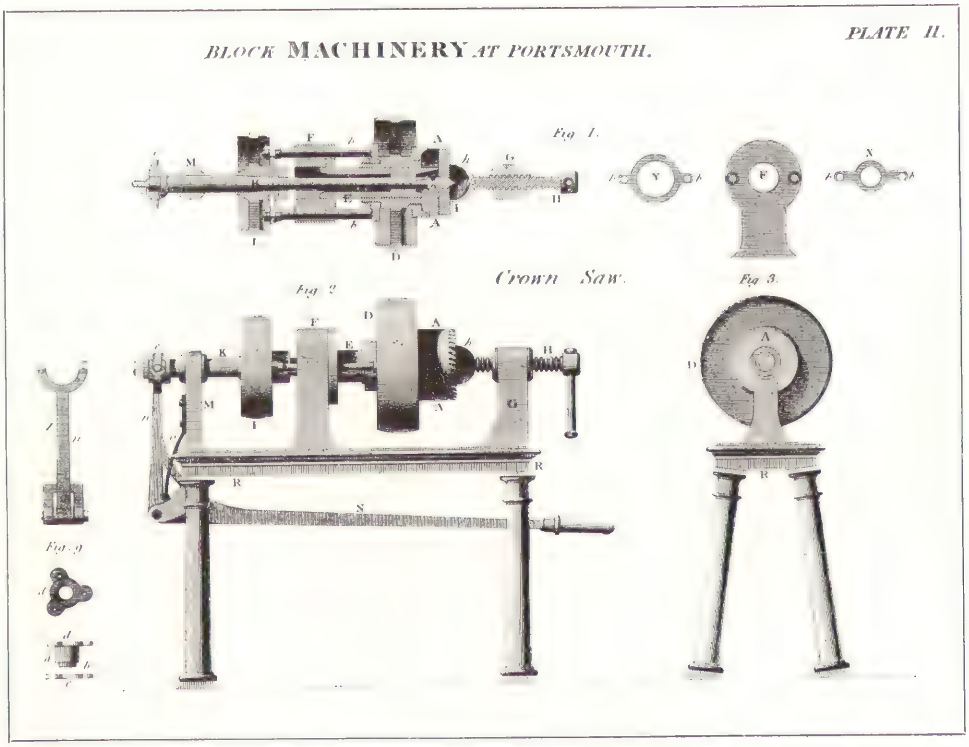
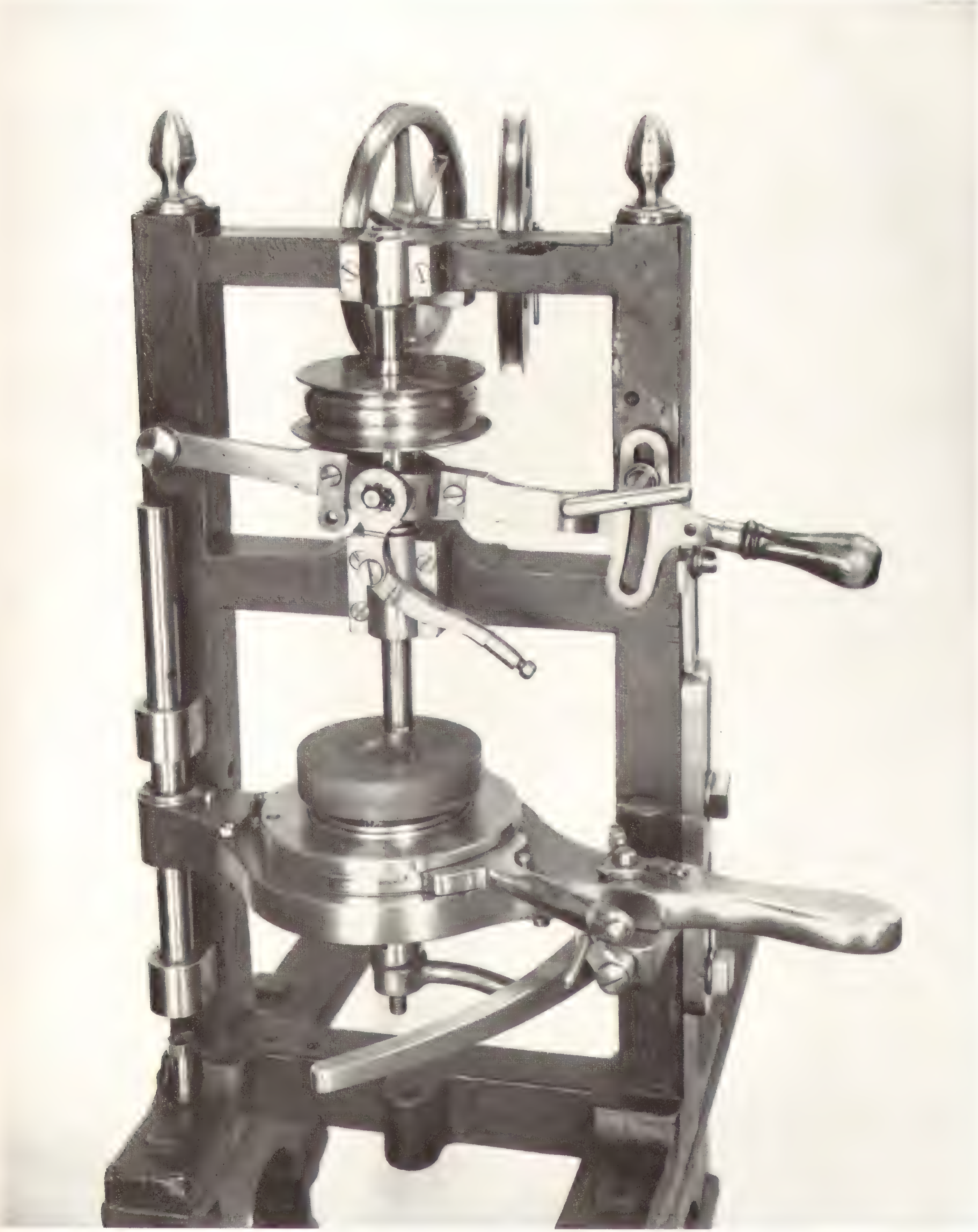


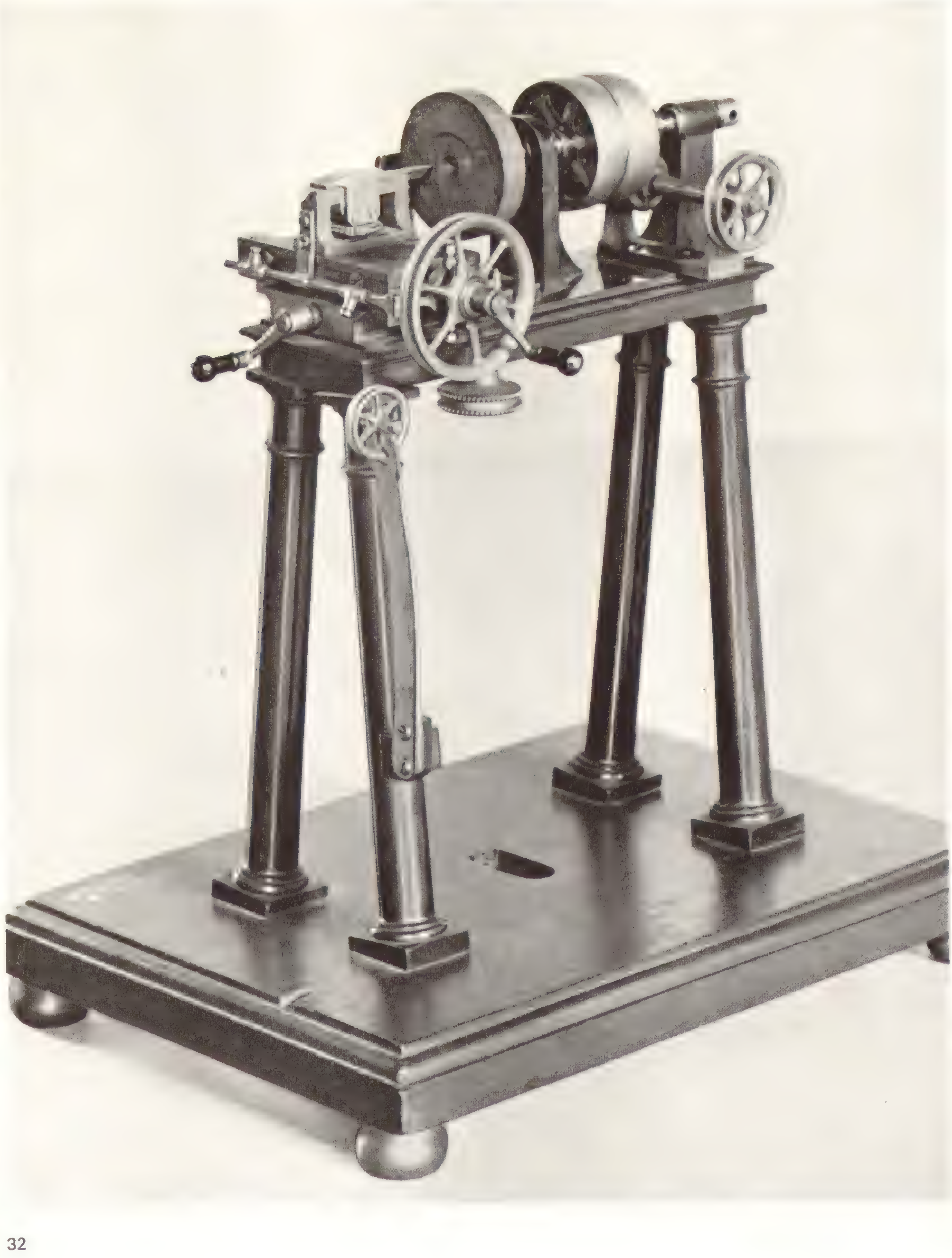
27 Rounding saw (*in the Science Museum Collections*)

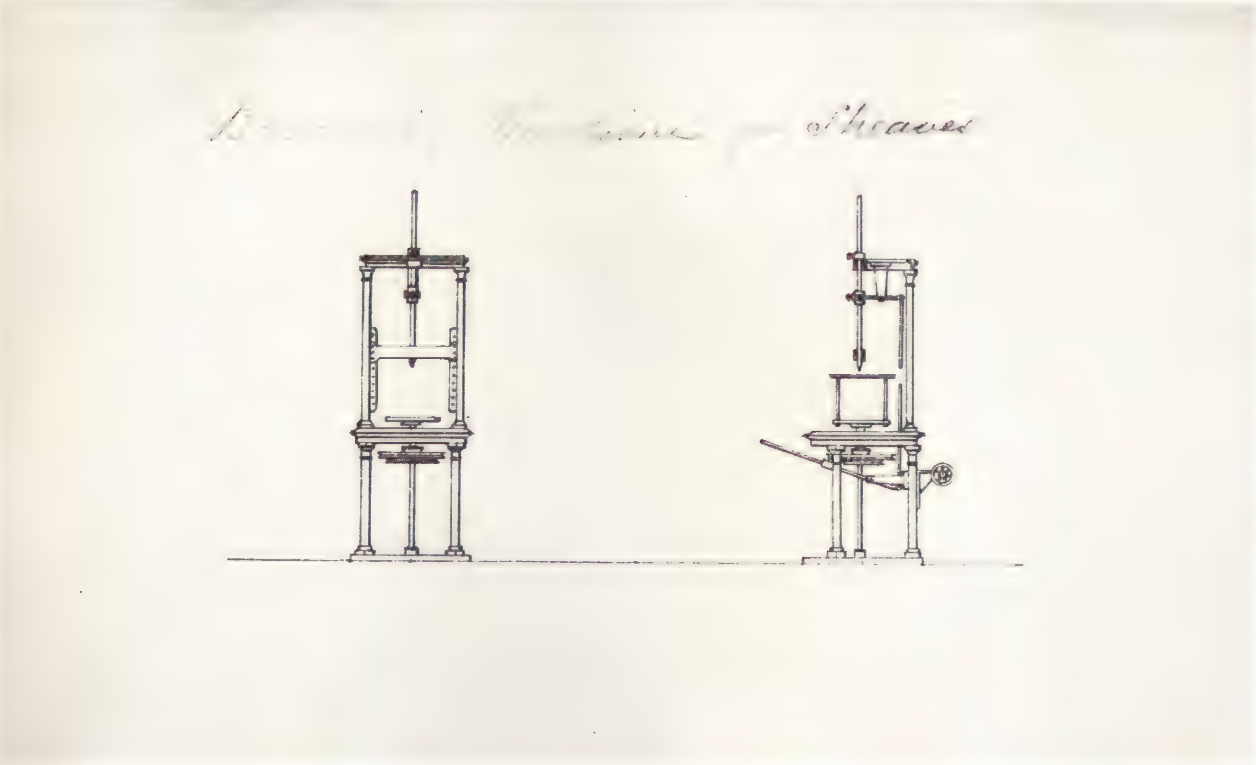


28 Rounding saw, from Rees's *Cyclopaedia*

29 Opposite: Coaking machine (*in the Science Museum Collections*)

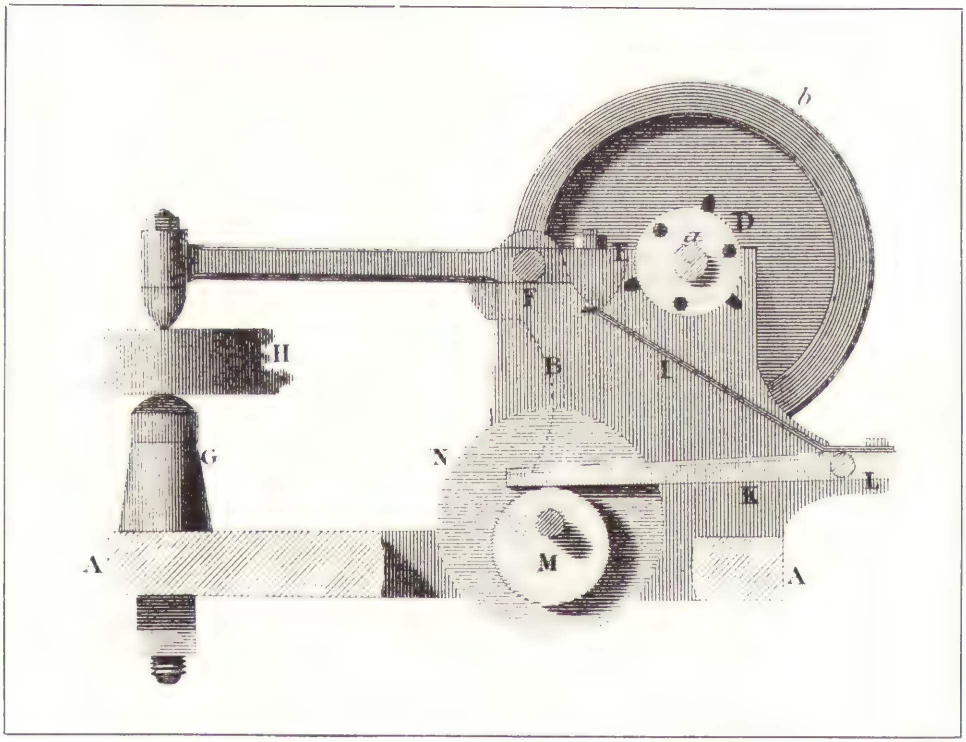




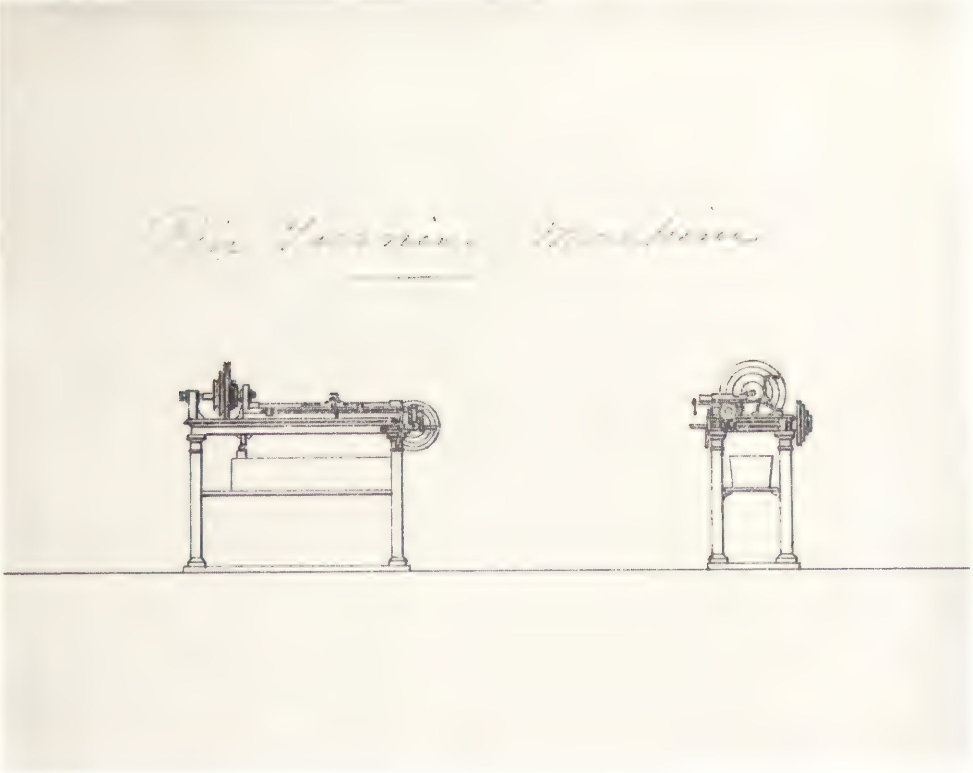


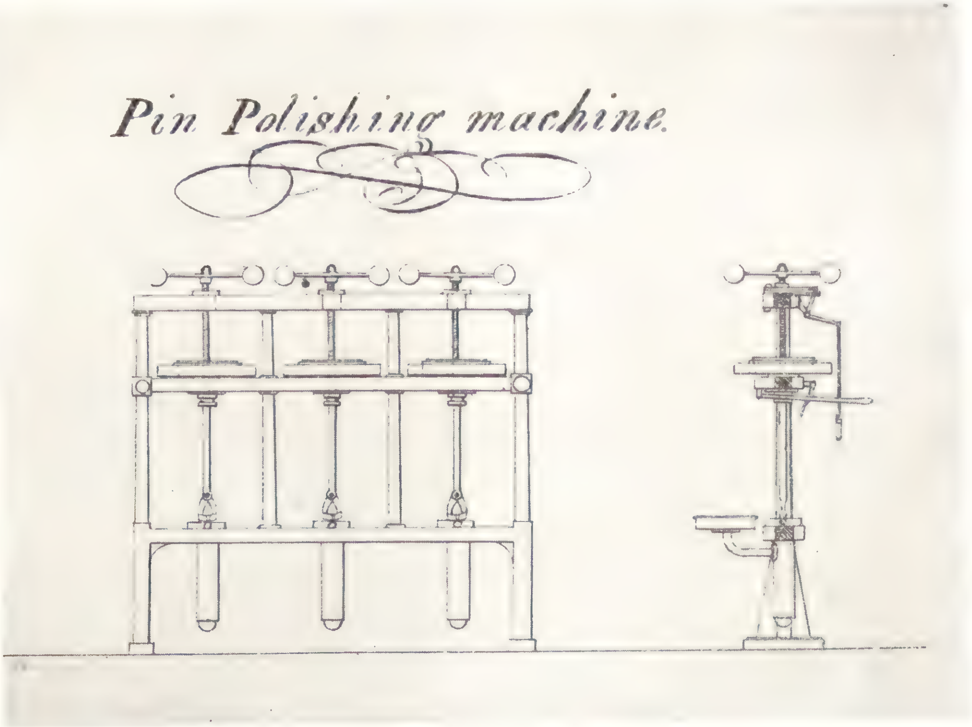
31 Above:
Broaching engine from Brunel's sketchbook, original size (*in the National Maritime Museum*)

32 Right:
Rivetting hammer from Rees's *Cyclopaedia*



30 Opposite:
Face-turning lathe—original models (*in the National Maritime Museum*)





33 Above:
Pin turning machine, from Brunel's sketchbook, original size
(*in the National Maritime Museum*)

34 Below:
Pin polishing machine, from Brunel's sketchbook, slightly reduced
(*in the National Maritime Museum*)

3 Controversy about the identity of the inventor

The account of the machinery written by John Farey, which appeared in Rees's *Cyclopaedia*[1], unequivocally ascribed its invention to Brunel. This view was unchallenged until 1852, when Bentham's widow, writing[8] as M.S.B , attributed the invention of the block-making machinery almost exclusively to Bentham, at the same time impugning Brunel's competence and integrity. The death two years previously of Brunel, the last of those most closely concerned, precluded a reply, so that Lady Bentham's attack had the effect of creating prolonged uncertainty as to the respective contributions of Bentham and Brunel to the mechanisation of block manufacture.

James Nasmyth, who had been Maudslay's personal assistant, writing[9] fifty four years after the event, and describing a visit paid with Maudslay to the Admiralty Museum—where he saw the models of the block-making machinery—said: 'Most of these were the result of Maudsley's [*sic*] own skilful handiwork. He also designed, for the most part, this wonderful and complete series of machines. Sir Samuel Bentham and Mr Brunel had given the idea, and Maudsley realised it in all its mechanical details'.

Both these views, the latter in anticipation, were refuted by Joshua Field, who had been first a draughtsman at Portsmouth Dockyard, then in 1804 had been transferred to Bentham's office, and finally in 1805 joined Maudslay, by whom he was eventually taken into partnership.

In a statement to Beamish he said[3] 'The works in progress, when Mr Brunel arrived were a new steam engine and some buildings intended for the reception of machinery, which General Bentham had proposed to erect, but had not erected. The General had already introduced saws of various kinds, and machines for tongueing, grooving, and rabetting timber; but there was no machinery whatever especially applicable to block making. That was altogether the invention of Mr Brunel. The character of the drawings was different from any we ever had before—the proportion of the parts—the whole thing, in short; and I never once heard, during all the time of my connection with the dockyard, with General Bentham, with Mr Goodrich, and with Mr Maudslay, that any one ventured to deny Mr Brunel's claims to be the sole inventor of the block machinery'.

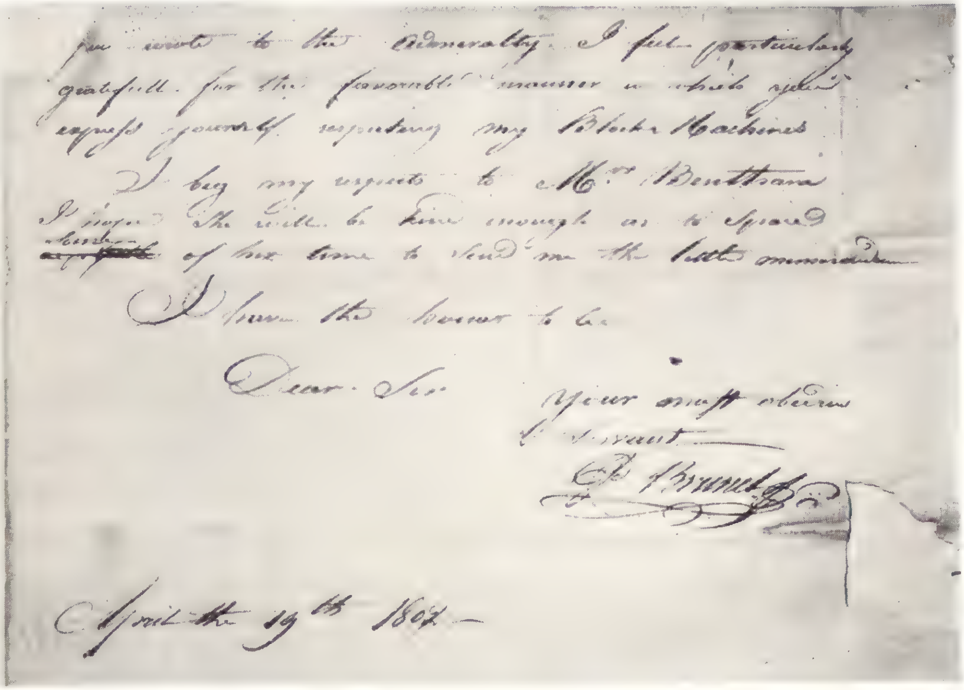
Nevertheless Field's testimony has not been enough to discredit the claims made for Bentham and Maudslay; and the controversy has continued to the present day[2] with attempts[6] to compromise by judicious allocation of the credit between the leading figures. It is, therefore, of interest to see what light *The Goodrich Papers*, the letters of Bentham and Brunel, and other unpublished material throw on the controversy.

A letter from Brunel to Bentham of 19th April, 1802, which is preserved in the Science Museum, refers to the models, and the latter part of it is reproduced as figure 35. The relevant portion reads: 'I have not yet compleated the little Machines although I have been constantly at work since I wrote you last the delay is owing to my having made a small instrument to assist me in cutting the screws.

The Gentleman who has given me your letter has shown me the copy of the one you wrote to the Admiralty. I feel particularly gratefull for the favorable manner in which you express yourself respecting my Block Machines'.

It is inconceivable that Brunel should have thus referred to 'my Block Machines' in a letter to Bentham, if the latter had indeed been the true inventor.

On 7th June 1803 Brunel, writing to Bentham, advised the appointment of James Burr '. . . on account of his being already so well practised in the working wood by your machinery of various kinds, I cannot but express my wish that he might be entrusted with the management of my machinery for making Blocks and Block maker's wares'. Bentham forwarded the above letter with a letter[10] dated 11th June, 1803 to the Secretary of the Admiralty in which he endorsed Brunel's recommendation: 'But as Mr Brunel's apparatus for making Blocks, however important, will form



you wrote to the Admiralty. I feel particularly
gratefull for the favorable manner in which you
express yourself respecting my Block Machines.
I beg my respects to Mrs Bentham
I hope She will be kind enough as to spare
[illegible] of her time to send me the little memorandum
I have the honor to be
Dear Sir
Your most obedient
servant
Brunel

April the 19th 1802

35 Conclusion of a letter from M. I. Brunel to Brigadier General Bentham (*in the Science Museum Collections*)

a part only of the Machinery which is or will be erected in that Dockyard for working wood, I see no reason why the same person should not be charged with the whole of this Machinery, including all such engines constructed on the principles of those which I had long ago put in practise, as well as those of Mr Brunel's invention'. He went on to say: 'Mr J. Burr should . . . be directed to take upon himself the care and management of Mr Brunel's Machinery for making blocks, as well as of such small articles of my machinery as are now in use in that Dockyard . . .'.

36 Sir Samuel Bentham 1757-1831 Miniature by A. Edridge (*in the National Portrait Gallery*)

On 10 September Bentham wrote[10] referring to 'an application from Mr Brunel to the Navy Board for an advance of £200 over and above the sum already advanced to him according to the estimate on account of the first set of his machinery for making Blocks, I would beg leave to state for their Lordships' information that this increase of expense beyond the original estimate has arisen in consequence of Mr Brunel's having contrived some considerable improvements in various parts of the machinery since the time when that estimate was made, and that those improvements having been explained by Mr Brunel to me, they appeared so evidently advantageous that I could do no otherwise than assent to them.' These letters clearly show the respective parts played by the two men.

That Maudslay was not the designer of the machinery, but worked to the instructions of Brunel is evident from the following quotation from a letter[11] dated 6 May 1806, in which the Commissioners directed the Navy Board to order additional machines: 'Mr Simon Goodrich, in the absence of the Inspector General of Naval Works, having submitted to us a Letter which he received from Mr Brunel, proposing an additional Engine for turning Iron Pins and two additional Riveting Engines for the use of the Wood Mills in Portsmouth Dock Yard; and as, for the reasons given by Mr Brunel these additional Engines are very necessary, Mr Goodrich has recommended that Mr H. Maudslay who has supplied the other Engines for Block-making, should receive directions to furnish those now wanted, according to Mr Brunel's Drawings and Directions.'

Finally there is the evidence of Brunel's sketchbook[7] that the machines were made from his drawings. Where a dimensioned drawing can be identified with an existing machine a check has been made by actual measurement. Thus the second size mortising machine from the first set made is the machine at the Science Museum (figure 15). All the dimensions given in the sketchbook (figure 14) agree closely with those of the machine with a single unimportant exception. Similar agreement applies in the case of the small shaping engine (figures 18 and 20) and the small scoring machine (figure 24). Thus Maudslay made at least these three important machines in accordance with the designs in Brunel's sketchbook, though he doubtless worked from larger and more finished drawings, as implied by Field. Incidentally Brunel's ability to express his ideas by means of adequate mechanical drawing derived from his training as a French officer, when he had presumably benefited indirectly from the teachings of Gaspard Monge[2].

The coaking machine differs in some respects from those in the sketchbook particularly in the arrangement for indexing. Perhaps this is one of the improvements mentioned by Bentham. The sketchbook gives sketches only of the boring machine, the lignum vitae saw, and the rounding saw; but these are in agreement with the actual machines.

Nothing in the foregoing discussion should be taken as being in any way detrimental to the reputation of Bentham. Rather does he deserve great credit for appreciating the value and practicability of Brunel's proposals and for giving him the administrative support necessary for them to be put into effect. It is indeed remarkable that the first large mass-production undertaking should have been launched not by private enterprise, and indeed against established commercial opinion, but by a traditionally conservative public department. This the country at a time of war owed entirely to Bentham. No one reading through the Bentham correspondence could suppose that with the great variety of matters requiring his attention he would have had time to design or to superintend personally the construction of the block-making machinery, though his own technical background made him exceptionally competent to judge it.

37 Opposite:
Henry Maudslay
1771-1831
Lithograph by
H. Grevedon, 1827
(*in the
Science Museum
Collections*)

Henry Maudslay was born in 1771 and set up in business on his own account only in 1797 after having been employed by Bramah for eight years. His work on the block machinery was his first important job. The wooden-framed machines he built for Bramah and his original screw-cutting lathe of c. 1800, though adequate for their work, do not have the elegant appearance of Brunel's machinery. The mouldings and the Tuscan columns of the block machinery go beyond the necessities of functional design and are features to be encountered in Maudslay's subsequent work. The high standard of Maudslay's workmanship had already been noticed and had recommended Brunel's attention to him as a person suitable to undertake the construction of the models and later of the machinery itself. It is, however, probable that Maudslay had more to learn than to impart from his engagement early in his career on this important contract and that he learnt much from his association with Brunel, which was later transmitted to his employees and thereby influenced machine-tool development in the first half of the 19th century[12].

The letters quoted and the evidence of the machines themselves confirm that Brunel invented the block-making machinery and nothing has been found to support the assertions of Lady Bentham and Nasmyth to the contrary. Brunel undoubtedly deserves the credit for conceiving, designing, and putting into operation this sequence of special-purpose machines, which has become historic as the first substantial application of machine tools to mass production.

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5 Science Museum *The Goodrich papers*

6 Forward, E.A, 'Simon Goodrich and his work as an Engineer' Pt 1 1796-1805 *Transactions of the Newcomen Society* III 1922-23 pp 1-15

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11 National Maritime Museum, Letter Book ADM/Q 3323

12 Gilbert, K.R, *Machine Tools*, Catalogue of the Collection—Introduction. Science Museum London 1965

Acknowledgements

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